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Please see the attached preliminary revised draft sections of the Kalamazoo River Area 1 FS. Please keep in mind that this draft submittal reflects revisions needed to address the following seven items, as previously agreed during our January 8, 2014 conference call. Figures and Tables that were revised or are new are also included with this e-mail.

1. TBERA (same as that transmitted on Dec 20, 2013)
2. RAO1 (same as that transmitted on Dec 20, 2013)
3. Sediment and fish PRGs
4. Time projections for fish tissue to meet the PRGs specified in RAO1
5. Inclusion of an additional hot spot in remedial alternatives S-3 and S-4
6. Additional sampling and concurrence with USEPA and MDEQ on remedial footprint as part of remedial alternatives S-3 and S-4
7. Identification of a remedial reach for remedial alternatives S-3 and S-4 with pre- and post-remedial SWACs

In addition to the above, we removed the scoring/ranking from the comparative analysis in Section 4. The above items were addressed as revisions to Sections 1 through 4.

After your review and agreement with the revisions submitted, we will revise all sections of the document based on the your comments on the items not listed above.

I look forward to meeting with you on Thursday and discussing these revisions.

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LIST OF A BREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Definition
95% UCL	95 percent upper confidence limit of the mean
95% UPL	95% upper prediction limit
ABSA	Aquatic biota sampling area
AAPD	Average annual percent declines
AOC	Agreement and Order on Consent
ARAR	applicable or relevant and appropriate requirement(s)
ASTM	Alternatives Screening Technical Memorandum
BAF	bioaccumulation factor
BBL	Blasland, Bouck & Lee
BEHI	Bank erosion hazard index
BERA	Baseline Ecological Risk Assessment
BHHRA	Baseline Human Health Risk Assessment
BSAF	biota-to-sediment accumulation factor
CAA	Clean Air Act
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
COC	constituent of concern
CSM	Conceptual Site Model
CWA	Clean Water Act of 19972
cy	cubic yard(s)
EC	Engineering Controls
EPC	Exposure point concentration
EU	Exposure unit
FPS	floodplain soil
FS	Feasibility Study
Georgia-Pacific	Georgia-Pacific, LLC
GIS	Geographic Information System
GLSFATF	Great Lakes Sport Fish Advisory Task Force
gpm	gallon(s) per minute
GPS	Global Positioning System
GRA	General Response Action
HHRA	Human Health Risk Assessment
HI	Hazard index(indices)
HQ	Hazard quotients
IC	Institutional Controls
kg/day	kilogram(s) per day
LOAEL	Lowest observed adverse effects level
LTM	Long-term monitoring
MDCH	Michigan Department of Community Health
MDEQ	Michigan Department of Environmental Quality
mg/kg	milligram(s) per kilogram
Millennium	Millennium Holdings, LLC
MIOSHA	Michigan OSHA
MNR	Monitored Natural Recovery

Abbreviation or Acronym	Definition
MSU	Michigan State University
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
ND	nondetect
NEA	Northeast Analytical, Inc.
ng/L	nanograms(s) per liter
NOAEL	No observed adverse effects level
NREPA	Natural Resources and Environmental Protection Act of 1994
OSHA	Occupational Safety and Health Administration
OSI	Ocean Surveys, Inc.
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbon(s)
PCB	polychlorinated biphenyls
POTW	publicly owned treatment works
PPE	personal protective equipment
ppm	part(s) per million
PRG	Preliminary Remedial Goals
PRP	potentially responsible party
RAL	Remedial action level
RAO	Remedial Action Objectives
RBC	risk-based screening concentration(s)
RBC_{fish}	risk-based concentration for fish tissue
RBC_{soil}	risk-based floodplain soil concentration
RCRA	Resource Conservation and Recovery Act of 1976
RfD	reference dose
RI	Remedial Investigation
RM	river mile
ROD	Record of Decision
RTK GPS	real-time kinematic global positioning system
Site	Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site
SOW	Statement of Work
SRD	Substantive Requirement Document(s)
SRI	Supplemental Remedial Investigation
SVOC	semivolatile organic compounds
SWAC	surface-area weighted average concentration
SWDA	Solid Waste Disposal Act
TBC	to be considered
TBERA	Terrestrial Baseline Ecological Risk Assessment
TCL	Target Compound List
TCLP	toxicity characteristic leaching procedure
TCRA	Time-critical removal action
TEQ	toxic equivalent
THI	target hazard index
THQ	target hazard quotient
TMV	toxicity, mobility, and volume
TOC	total organic carbon
TR	target risk
TRV	Toxicity reference values
TSCA	Toxic Substances Control Act of 1976

Abbreviation or Acronym	Definition
TSS	total suspended solids
UCSB	University of California at Santa Barbara
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VOC	volatile organic compounds
WCS	water-level control structure
YOY	young of year
µg/L	microgram(s) per liter

1.0 INTRODUCTION

Georgia-Pacific, LLC (Georgia-Pacific) is conducting a Supplemental Remedial Investigation/Feasibility Study (RI/FS) for Operable Unit 5 (OU-5) of the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site (Site or Superfund Site) in Kalamazoo and Allegan Counties of southwest Michigan (Figure 1-1). This work is being performed with oversight of the U.S. Environmental Protection Agency (USEPA) under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and an Administrative Settlement Agreement and Order on Consent (AOC) signed by Georgia-Pacific on February 21, 2007.

OU-5 encompasses 80 miles of the Kalamazoo River from Morrow Dam east of Kalamazoo to the river mouth at Lake Michigan, plus a stretch of Portage Creek in Kalamazoo. The other OUs are the Allied Paper, Inc. Landfill (OU-1), Willow Boulevard/A-Site Landfill (OU-2), King Highway Landfill (OU-3), the 12th Street Landfill (OU-4), and the former Plainwell Mill (OU-7). This Feasibility Study Report (FS) addresses Area 1 of OU-5, which is the 22-mile reach of the Kalamazoo River from Morrow Dam to the former Plainwell Dam, plus a 3-mile stretch of Portage Creek from Alcott Street to its confluence with the Kalamazoo River (Figure 1-2).

The purpose of this Area 1 FS is to evaluate sediment and floodplain soil remedial alternatives and present information in a manner consistent with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP; 40 Code of Federal Regulations [CFR] 300.430(e)(6)) to select an Area-specific remedy (USEPA 2007a). This Area 1 FS Report was prepared in accordance with USEPA's Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA 2005b) and the Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA 1988a), and CERCLA Compliance with Other Laws Manual, Parts I and II (USEPA 1988b; USEPA 1989).

1.1 PURPOSE AND REPORT ORGANIZATION

This revised Area 1 FS has been prepared to support the selection of a remedy for Area 1 that is protective of human health and the environment. This Report includes the following information:

- Remedial Action Objectives (RAOs) in accordance with Section 300.430(e)(2)(i) of the NCP for impacted media that require a remedial action based on the findings and risk assessments presented in the Area 1 Supplemental Remedial Investigation (SRI) Report (ARCADIS 2012a)
- Identification and screening of remedial technologies
- Development of remedial alternatives for protection of human health and the environment
- Evaluation of remedial alternatives using the nine CERCLA criteria (USEPA 1988a)
- Comparison of remedial alternatives

This document is organized into the following sections:

- Section 1.0 – Introduction
- Section 2.0 – RAOs/General Response Actions
- Section 3.0 – Technology Identification/Screening and Alternatives Development

- Section 4.0 – Sediment Remedial Alternatives Analysis
- Section 5.0 – Floodplain Soil Remedial Alternatives Analysis
- Section 6.0 – Residential Floodplain Analysis
- Section 7.0 – Summary and Recommendations
- Section 8.0 – References

1.2 SITE HISTORY

In 1990, the Site was added to the National Priorities List due to the presence of polychlorinated biphenyls (PCBs) in the sediment, fish, and surface water of the Kalamazoo River. Georgia-Pacific has, since 1991, entered into a series of agreements with the USEPA and the State of Michigan to carry out investigations under Superfund to identify sources of PCBs to the river; assess the nature and extent of PCB concentrations in relevant media, and complete cleanup work in and along the river.

The Kalamazoo Mill, which Georgia-Pacific purchased in 1967, was one of a group of mills in the Kalamazoo area that recycled various types of paper stock starting in the 1950s. Materials that were recycled included carbonless paper, which from at least 1954 until 1971 contained PCBs as an ink transfer agent. PCBs were released into the mills' waste streams, and eventually into the Kalamazoo River, through the recycling process. Non-paper sources of PCBs have also been identified throughout the watershed.

1.2.1 Responsible Parties

On February 21, 2007, Georgia-Pacific and Millennium Holdings, LLC (Millennium) jointly entered into an AOC with USEPA (CERCLA Docket No. V-W-07-C-864). The 2007 AOC describes a series of supplemental remedial investigations and feasibility studies (SRIs/FSs) to be carried out at the Superfund Site and is known as the SRI/FS AOC.

Following the Millennium bankruptcy in January 2009, Georgia-Pacific is the sole company performing investigation and cleanup work in OU-5. Georgia-Pacific has completed remedial work at the Willow Boulevard/A-Site (OU-2) and the King Highway Landfill (OU-3). Another responsible party, Weyerhaeuser Company, is engaged in cleanup work at the 12th Street Landfill (OU-4) and the former Plainwell Mill (OU-7).

Georgia-Pacific implemtented two Time Critical Removal Actions (TCRAs) in the downstream portion of Area 1 betweeen 2007 and 2010. The first action was performed from 2007 to 2009 to remove a portion of the former Plainwell Dam and contaminated floodplain soil and sediment in the former Plainwell Impoundment. The second action was performed in 2009 and 2010 to remove contaminated floodplain soil and sediment in the Plainwell No. 2 Dam area. A USEPA-led TCRA to remove paper residuals from the former Bryant Mill Pond located on Portage Creek was performed between 1998 and 1999. A second USEPA-led TCRA is currently being implemented in the city of Kalamazoo along the stretch of Portage Creek in Area 1 between East Stockbridge Avenue and the confluence with the Kalamazoo River (USEPA 2011). In addition, cleanup work at the other OUs and former mill sites has occasionally extended into OU-5, including removal and/or backfilling to address the presence of PCBs or papermaking residuals in shoreline areas and in near-shore sediment and floodplain soil. Summaries of the TCRA actions and adjacent cleanup activities affecting OU-5 are described in more detail in Section 1.3.4.

1.2.2 OU-5 Areas

Attachment A of the SRI/FS AOC defines a breakdown of OU-5 into seven Areas (Figure 1-1) and includes a Statement of Work (SOW) that sets forth the requirements for conducting the Site SRIs/FSs. The SRI/FS process and SOW activities are being performed in each area individually. The seven areas are:

- Area 1: Morrow Dam to Plainwell Dam, which includes a stretch of Portage Creek from Alcott Street to its confluence with the Kalamazoo River (Figure 1-2)
- Area 2: Plainwell Dam to Otsego City Dam
- Area 3: Otsego City Dam to Otsego Dam
- Area 4: Otsego Dam to Trowbridge Dam
- Area 5: Trowbridge Dam to the Allegan City Dam
- Area 6: Allegan City Dam to Lake Allegan Dam (also known as the Calkins Bridge Dam)
- Area 7: Lake Allegan Dam to Lake Michigan

1.2.3 Site Setting

OU-5 extends from Morrow Dam downstream to the mouth of the Kalamazoo River at Lake Michigan, spanning approximately 80 miles of river, and traversing urban, rural, forested, agricultural, and marshland areas. Flow conditions throughout the Site vary intermittently between free-flowing and impounded reaches. Topography next to the river varies as well, ranging from an incised valley with narrow floodplains in the upper reaches of the Site to flatter topography with adjacent marshes downstream of Lake Allegan, which is the largest and most downstream impoundment on the Kalamazoo River.

Area 1 is the most upstream segment of the Site, which flows through the communities of Comstock, Kalamazoo, Parchment, and Plainwell. Area 1 includes 22 miles of the Kalamazoo River from Morrow Dam to the former Plainwell Dam and 2 miles of Portage Creek from Alcott Street downstream to the confluence with the Kalamazoo River (Figure 1-2). Several former paper mills and disposal areas associated with the Site are located along this reach of the river and Portage Creek. To date, remediation work along the Kalamazoo River and the adjacent OUs has included multiple PCB source control activities in Area 1 (summarized in Section 1.3.4). Most of Area 1 is a free-flowing river with bed slopes of about 2 to 6 feet per mile, which result in relatively rapid flow velocity. Free-flowing conditions are present with the exception of low head former diversion structures (Plainwell No. 2 Dam) upstream of the town of Plainwell. The urban Kalamazoo region between river mile (RM) 72.4 and RM68.4 (i.e., starting in Section 2 and continuing into Section 4) is a lower gradient section with a bed slope of approximately 2 feet per mile. This part of the river in Area 1 historically accumulated thicker deposits of sediment in some areas.

Land use along the river and creek in Area 1 varies, with industrial, commercial, municipal, recreational, and residential areas near the population centers of Comstock, Kalamazoo, Parchment, and Plainwell. Between the population centers, land use is dominated by large areas of State-owned forested land and privately owned forested and agricultural properties. These are interspersed with residential and recreational parcels.

The river bottom is predominantly sand and gravel with some fine-grained sediment. Fine-grained sediment occurs in areas along the channel margins and in side channels.

The average depth of water in the eight sections of the Kalamazoo River established during the SRI work ranges from 2.4 to 6.2 feet, and from 0.8 foot to 1.5 feet in the four sections of Portage Creek. The greatest water depths occur in the segment from RM71.65 to RM70 (Portage Creek Confluence to Mosel Avenue in Section 3) and the shallowest depths occur between RM76.50 and RM73.1 (Morrow Dam to King Highway in Section 1).

In the urban region and in the nearly 2-mile reach of Portage Creek in Area 1, shorelines have been extensively altered as a result of industrial and municipal construction. Consequently, a variety of bank types can be found in the river and Portage Creek, from natural, vegetated banks to hard concrete apron shorelines.

There are 26 bridge crossings over 22 miles of the river between Morrow Dam and the former Plainwell dam (including the mill race and side channels). Outside the developed stretches, the riverbanks and adjacent lands are in a largely natural condition with extensive vegetation.

Historically, sediment accumulation occurred within the former Plainwell Impoundment and to a lesser extent in the Plainwell No. 2 Dam Area due to the historical presence of dams. Opening and partially removing the former Plainwell Dam resulted in temporarily unstable riverbanks that served, to varying degrees, as ongoing sources of PCBs to the river. As part of the two TCRA projects completed in these locations, the riverbanks were cut back, reconstructed and restored with natural habitat. Rock armoring was also added in much of the TCRA areas. Targeted deposits of floodplain soil, exposed former sediment, and in-channel sediment were excavated and disposed offsite. These TCRA events are summarized in Section 1.3.4. These removal actions controlled erosion of exposed former sediment and removed targeted floodplain soil with high PCB concentrations. In both locations, the riverbanks and revegetated areas are monitored and maintained to support the established clean buffer zones and desired habitat. Monitoring activities and results are documented in annual monitoring reports submitted to USEPA. A final inspection of the former Plainwell Impoundement TCRA area was performed on June 12, 2013. The final inspection of the Plainwell No. 2 Dam Area TCRA site is expected to be completed in the first half of 2014.

The shoreline of the portion of Portage Creek included in Area 1 – the stretch from Alcott Street just downstream of the Allied Paper, Inc. Operable Unit (OU1 of the Site) to the confluence with the river – has been extensively altered. The first half mile of the creek downstream of Alcott Street to East Stockbridge Avenue has a very steep gradient, with slopes of 35 feet per mile in the first 0.16-mile stretch, and 18 feet per mile over the next 0.34 mile. The average sediment thickness in these reaches is 0.4 foot and 0.8 foot, and the water depth is between 0.8 and 0.9 foot. Downstream of East Stockbridge Avenue, the slope decreases and sediment thicknesses increase. The stretch downstream of East Stockbridge Avenue is the focus of an ongoing USEPA-led TCRA to address areas of higher PCB concentrations in creek bed sediment. This removal action also includes removal of floodplain soil from an area with elevated PCB concentrations along Portage Creek. Some sediment that exceeded the PCB remedial action level (RAL) concentrations of 10 milligrams per kilogram (mg/kg) were left in place because they were difficult to access or represented relatively small deposits (see Section 1.3.4.3).

1.2.4 Area 1 SRI/FS Progress

The following reports document activities completed in Area 1 in accordance with the SOW. These reports support the development and evaluation of remedial alternatives for sediment and floodplain soil in this FS.

- *Area 1 Supplemental Remedial Investigation/Feasibility Study Work Plan* (Area 1 SRI/FS Work Plan; ARCADIS BBL 2007a) – The Area 1 SRI/FS Work Plan (Task 1.3 of the SOW) outlines activities designed to develop an "SRI that fully determines the nature and extent of the release or threatened release of hazardous substances, pollutants, or contaminants" and an "FS that identifies and evaluates alternatives for remedial action to protect human health and the environment." The efforts described in the USEPA-approved Area 1 SRI/FS Work Plan have either been completed, or determined to be unnecessary based on existing information and the results of early phases of the supplemental work.
- Multi-Area FS Documents – To guide the Area 1 FS and provide consistency and efficiency across the seven Areas of OU-5, four Multi-Area FS Planning Documents (ARCADIS 2010a, 2010b, 2010c, 2010d) were prepared as the first step in developing the FS Reports. As stated in Task 1.2.2 of the SOW, these USEPA-approved Multi-Area FS Planning Documents are intended to "set forth general approaches and concepts with the intent of streamlining preparation of work plans and minimizing review times for future deliverables" (USEPA 2007a).
- Area 1 SRI Report (ARCADIS 2012a) – The Area 1 SRI Report documents the nature and extent of PCBs and the assessment of risks to human health and the environment in Area 1 in accordance with Task 3 of the SOW. In addition, the Area 1 SRI Report provides Area 1 background information, summarizes investigation data, describes Area 1 characteristics, and describes fate and transport processes. The Area 1 SRI Report was conditionally approved by USEPA on June 28, 2012 and was finalized on August 21, 2012. Area 1 Alternatives Screening Technical Memorandum (ASTM; ARCADIS 2012b) – The Area 1 ASTM summarized the work already completed in Area 1 (RI and source control activities); preliminary RAOs and Preliminary Remedial Goals (PRGs) based on the baseline human health and ecological risk assessments in the Area 1 SRI Report; documented the remedial alternatives development and screening process; and presented the resulting array of alternatives to be evaluated in the Area 1 FS Report. The Area 1 ASTM was submitted to USEPA on April 22, 2012, after a series of planning meetings and discussions among Georgia-Pacific, USEPA, and the MDEQ. USEPA and MDEQ provided comments on the Area 1 ASTM on August 1 and 10, 2012, respectively. Georgia-Pacific prepared responses to the USEPA comments and submitted the responses for review on August 22, 2012. Preliminary responses were submitted to MDEQ on September 6, 2012, and discussed via conference call on September 12, 2012. The Area 1 ASTM was revised based on Agency comments and submitted as an appendix to the Draft Area 1 FS in October 2012.
- Draft Area 1 FS (ARCADIS 2012c) – A Draft Area 1 FS presented a summary of site conditions and an evaluation of remedial alternatives for Area 1 sediment and floodplain soil. USEPA and MDEQ comments on the Draft Area 1 FS were provided on February 5, 2013, and February 15, 2013, respectively. Planning meetings with the agencies and agency representatives to review Agency comments and discuss approaches to revising the FS were held on February 20, 2013; April 3, 2012; and May 9–10, 2013. Work Group meetings with representatives for USEPA, MDEQ, and Georgia-Pacific also occurred weekly from April to early June 2013 to assess data applicability and to finalize calculation methods for determining PCB surface-area weighted average concentrations (SWACs) and fish-tissue concentration trends.

1.3 AREA 1 SRI ~~AND RISK ASSESSMENT~~ SUMMARY

This section of the Report summarizes the physical characteristics of Area 1; PCB concentrations in sediment, floodplain soil, and fish tissue; human health and ecological risk assessments; and prior remedial actions performed in Area 1. The historical data collection activities are summarized in Table 1-1.

Area 1 has been divided into eight river sections* for the purpose of describing the variations in the physical and chemical characteristics of the sediment within this 22-mile stretch of the river. These Area 1 segments are defined by landmarks and RM measurements from the mouth of the Kalamazoo River at Lake Michigan, as listed below and shown on Figure 1-3:

- Section 1: Morrow Dam (RM76.50) to King Highway (RM73.10)
- Section 2: King Highway (RM73.10) to Portage Creek (RM71.65)
- Section 3: Portage Creek (RM71.65) to Mosel Avenue (RM70.00)
- Section 4: Mosel Avenue (RM70.00) to D Avenue (RM65.10)
- Section 5: D Avenue (RM65.10) to Railroad Bridge (RM59.40)
- Section 6: Railroad Bridge (RM59.40) to Plainwell No. 2 Dam (RM58.20)
- Section 7: Plainwell No. 2 Dam (RM58.20) to Main Street, Plainwell (RM56.65)
- Section 8: Main Street, Plainwell (RM56.65) to former Plainwell Dam (RM54.75)
- Mill Race: Plainwell No.2 Dam (RM58.20) to confluence near Main Street (RM56.60)

* Please note that in this Report, main sections of the text are referenced with a decimal designation (e.g., Section 1.0, Section 2.0, etc.) to distinguish them from the Area 1 river sections as designated above.

Fish tissue sampling locations/reaches are identified by a series of aquatic biota sampling area (ABSA) designations along the Kalamazoo River. The ABSAs applicable to Area 1 referenced by landmark are listed below and shown on Figure 1-3:

- ABSA 1: Kalamazoo River reference area upstream of Battle Creek (includes Ceresco Reservoir)
- ABSA 2: Morrow Lake reference area from the city of Battle Creek to Morrow Dam (immediately upstream of the Site)
- ABSA 3: Morrow Dam to Mosel Avenue
- ABSA 4: Mosel Avenue to Highway 131 Bridge
- ABSA 5: Highway 131 Bridge to former Plainwell Dam

1.3.1 Nature and Extent of Contamination

1.3.1.1 Sediment

Historical Sampling Events

Sediment data for Area 1 have been collected under various sampling programs since the original RI work in 1993/1994. During the RI, Area 1 was characterized and the available data were used to develop an understanding of spatial and historical PCB trends in sediment. These data were supplemented in 2000 by additional sediment sampling using the same field sampling and quality assurance/quality control protocols as used under the 1993/94 RI work plans.

Bank soil and sediment sampling was carried out in the former Plainwell Impoundment in 2003 and 2005–2006, respectively, to support the TCRA design efforts. A summary of the TCRA efforts performed in Area 1 is provided in Section 1.3.4. From 2007 through 2009, field investigations were performed in Area 1 to satisfy the requirements of the SRI/FS AOC and add

Table 1-1. Summary of Historical RI Activities and Data Available for Area 1[4]

Source	Investigation	Data Generated
Responsible Party Data[1]	**Remedial Investigations**	Sediment transect probing data, 1993
		Sediment PCB and total organic carbon (TOC) data, 1993
		Sediment particle size data, 1993
		Floodplain soil data, 1993
		Exposed sediment PCB and TOC data, 1993
		Surface water data, 1993
		Fish data, multiple locations, 1993
		Exposed sediment earthworm and mouse sampling, 1993
Responsible Party Data[1] (cont'd.)	**Supplemental Investigations**	Fish data, multiple locations, 1999
		Geotechnical sediment sampling, 1999
		Sediment PCB and TOC data, 1999-2000
		Ocean Surveys, Inc. (OSI) bathymetry maps, 1999
		Sediment erodibility data (Lick UCSB)[2], 1999
		Surface water PCB loading data, 1999-2000
		Erosion pin measurements, 2000-2002
		Ecological risk assessment sampling (Giesy MSU)[3] 2000-2003
		Finely sectioned sediment PCB, TOC, and radionuclide data, 1999
	Former Plainwell Impoundment Investigations	Plainwell bank profile survey data, 2003
		Plainwell top-of-bank PCB sampling, 2003
		Plainwell habitat description and classification, 2003
		Sediment sampling in support of removal design, 2006
Agency Data		MDEQ Long-Term Monitoring Data (surface water, fish), 1999, 2000, 2001, 2002-2008, 2009, 2011 (ongoing)
		USEPA Phase I (grid) sediment and soil sampling, 2001
		USEPA Phase II (radial) sediment and soil sampling, 2001

Notes:

1. Only data collected by Georgia-Pacific, USEPA, or MDEQ are included in this table. Weyerhaeuser has also collected data within the Site, but those data are not listed here.
2. The sediment erodibility/resuspension data were collected and analyzed under the direction of Dr. Wilbert Lick of the University of California at Santa Barbara (UCSB).
3. Supplemental ecological field sampling program was carried out by staff from the Michigan State University's (MSU) Aquatic Toxicology Laboratory - Department of Zoology and the National Food Safety and Toxicology Center under the direction of Dr. John Giesy of MSU.
4. Source: Table 2-1 Area 1 SRI Report (ARCADIS 2012a)

to the more than 4,100 PCB data points for Area 1 sediment and soil collected in 1993/1994 and 2000. The primary intent of the post 2000 SRI work was to address localized data gaps.

Sediment Sampling Summary

1993/94 and 2000 RI Sampling: Investigations of the Site began in 1993, and several entities – including the potentially responsible parties (PRPs) that have participated in the CERCLA process, USEPA, and the State of Michigan – have collected an extensive body of data for a variety of environmental media. More than 15,000 site-wide (Areas 1 through 7) samples were collected and analyzed before the start of the SRI work and the design of the TCRAs in the former Plainwell Impoundment and Plainwell No. 2 Dam Area. The samples were analyzed for various constituents including PCBs, metals, polycyclic aromatic hydrocarbons (PAHs), and pesticides. Analysis of non-PCB constituents is discussed in Section 3.0.

SRI Transect Sampling: As part of the Phase I SRI, 128 locations along 16 transects were probed between Morrow Dam and Main Street, Plainwell. From these transects, 183 sediment samples from 44 sediment cores were analyzed for PCBs. PCB concentrations ranged from nondetect (ND) to 210 mg/kg with surface (0-6 inch depth interval) sediment PCB SWACs for the various Area 1 sections ranging from 0.11 to 2.19 mg/kg. SWAC calculation methodology and results are discussed below. Approximately 81% (148 of 183) of the SRI sediment samples collected were less than 1.0 mg/kg, while approximately 3% (5 of 183) exceeded 50 mg/kg.

Resampling at 1993/94 and 2000 Transect Locations: In October 2007, additional surface sediment samples were collected from transect locations that were sampled during the 1993/1994 RI and the 2000 supplemental efforts. During this sampling event, 52 surface sediment samples collected between Morrow Dam and Main Street, Plainwell were analyzed for PCBs. PCB concentrations ranged from ND to 13 mg/kg. Approximately 81% (42 of 52) of sediment samples collected had PCB concentrations less than 1.0 mg/kg.

Sampling at Plainwell No. 2 Dam: From this study area, 202 sediment samples from 47 sediment core locations were analyzed for PCBs. PCB concentrations ranged from ND to 42 mg/kg. Approximately 88% (177 of 202) of sediment samples collected had PCB concentrations less than 1.0 mg/kg, while approximately 1.0% (2 of 202) exceeded 10 mg/kg.

Side Channel Sampling: An Area 1 side channel survey was performed to identify and evaluate potential sediment/PCB depositional areas. A total of 34 sediment samples from ten sediment core locations from selected side channel and oxbow areas were analyzed for PCBs. PCB concentrations ranged from ND to 6.1 mg/kg. Approximately 71% (24 of 34) of sediment samples collected had PCB concentrations less than 1.0 mg/kg.

Sampling between Crown Vintage Landfill and Plainwell No 2 Dam: Focused sampling at a sediment location in an embayment on the east side of the river at RM64 was the only location of the five revisited in July 2009 where additional step-out sampling was conducted. From this focused step-out sampling, 48 sediment samples from 11 core locations were analyzed for PCBs. PCB concentrations ranged from ND to 21 mg/kg. PCB concentrations in approximately 44% (21 of 48) of sediment samples collected in these areas were less than 1.0 mg/kg, while approximately 6.3% (3 of 48) exceeded 10 mg/kg.

Hot Spot Assessment Areas: Forty-two sediment cores were collected from the six hot spot assessment areas (i.e., locations where transect samples indicated PCB concentrations of 50 mg/kg or greater), resulting in 234 sediment samples for analysis of PCB, total organic carbon (TOC), solids, and grain size. Hot spot areas are discussed further in Section 4.0. PCB concentrations at sediment locations sampled as part of the hot spot assessment ranged from ND to 310 mg/kg. Approximately 51% (120 of 234) of sediment samples had PCB concentrations less than 1.0 mg/kg, with approximately 16% (38 of 234) exceeding 50 mg/kg.

Distribution of PCBs in Sediment

Most PCBs currently in sediment are associated with lower energy depositional areas of the river as described in the USEPA-approved Area 1 SRI Report (ARCADIS 2012a). Most of the river channel in Area 1 is in a condition of dynamic equilibrium (except for the former Plainwell Impoundment following the TCRA implemented from 2007 to 2009). Dynamic equilibrium defines a condition where sediment settle out of the water column during receding flows, but are susceptible to movement during increasing flows. The river in the former Plainwell Impoundment is non-depositional due to removal of the Plainwell Dam. Figures 1-4a through 1-4f depict the sediment PCB data in Area 1 categorized by depth, showing the highest PCB concentration detected in each of four depth intervals: 0 to 6 inches, 6 to 12 inches, 12 to 24 inches, and greater than 24 inches.

PCBs in Area 1 are broadly distributed in mostly pockets of fine-grained material over the 22-mile reach. PCB concentrations greater than 50 mg/kg in the river were identified as hot spot areas during SRI sampling events. The areas of these hot spots range from approximately 0.025 acre to 1.4 acres.

Concentrated deposits of PCBs are present in lower Portage Creek, sediment PCB hot spots near the city of Kalamazoo, and sediment in a side channel next to the Crown Vantage landfill area. The USEPA-led removal action in Portage Creek is remediating PCB deposits found there. Portage Creek currently represents an upstream source of PCBs to the river. Areas with PCB concentrations greater than 10 mg/kg are targeted for removal. USEPA estimates the post-removal PCB SWAC for Portage Creek will be approximately 1.8 mg/kg for sediment and soil, compared to the current pre-removal SWAC estimate of 6.1 mg/kg (USEPA 2012).

SWAC Methodology

A SWAC is a method of spatially calculating the mean (average) concentration of a constituent in sediment. Samples are collected throughout the area of concern, representative subareas are generated for each sample location, and a subarea-weighted average concentration is calculated to produce the SWAC. The subareas may be generated using several different methods such as grids or stream tubes. Stream tubes are longitudinal slices (“tubes”) of the river channel that capture the general hydrodynamic flow pattern of the river. Multiple parallel “tubes” provide bank-to-bank coverage of the river. The sides of the stream tube curve to match the centerline of the river when the river curves. The ends of the tubes are perpendicular to the river flow and are determined by the location of the sampling points, typically at the midpoint between adjacent sampling points (Figures 1-5a and 1-5b). Sediment transport along a river is generally parallel to the flow direction and sediment variability is generally much greater perpendicular to the flow of the river. A Work Group consisting of USEPA, MDEQ, and Georgia-Pacific representatives met weekly from April to early June 2013 to select appropriate SWAC calculation methods and data applicability. The results presented herein reflect the Work Group’s agreed-upon methods and data application.

SWACs, as calculated herein, are used as a tool to identify river sections that would be carried forward in the development of remedial alternatives in Section 3.0. Additional sampling would be performed for active remedial alternatives during remedial design to better define the remedial area prior to remedial action.

A Geographic Information System (GIS) can be used to facilitate the generation of stream tubes because of GIS’s ability to represent spatial data and provide an interactive user interface. Stream tubes can be generated automatically based on the centerline of the river and using the riverbanks as boundaries. These stream tubes can then be interactively refined based on existing sediment sample locations, additional knowledge of the river’s flow characteristics, and other pertinent information. A step-by-step description of the methodology used in GIS to process data, define stream tubes, and calculate SWACs for each section of Area 1 is described in Appendix A. A SWAC was calculated for Sections 1 through 8 of Area 1, the Plainwell Mill Race, and the Crown Vantage side channel (shown in Figure 1-2). A SWAC was estimated for three depth intervals: Interval 1 (0 inch–6 inches), Interval 2 (6–12 inches), and Interval 3 (12–24 inches).

Confidence Interval Calculations
A 90 percent confidence interval (corresponding to symmetrical lower 5 percent confidence limit and upper 95 percent confidence limit) was calculated on the Total PCB concentrations in sediment used for the SWAC for each Interval and section in Area 1. The data were checked for normality by interval. Confidence limits could not be calculated using a normal distribution primarily due to the large number of NDs. The nonparametric Chebyshev bounds were calculated to approximate what the limits would be if the underlying distribution of the data could be mathematically described. Following methodology described in USEPA's ProUCL package, the Chebyshev lower 5 percent and upper 95 percent confidence interval bounds were calculated in R (R Development Core Team, 2009) for the SWACs using area weighted concentrations and variances in each section for the three depth intervals individually. These Chebyshev bounds calculate the minimum and maximum value that the confidence limits could be, regardless of the underlying distribution of the data. Thus, these bounds are overly conservative.

SWAC and Confidence Interval Results
Figures 1-5a and 1-5b are provided as an example to show sediment stream tubes in Interval 1 used to calculate SWAC values in Section 1. Plots of the stream tubes for all sections of Area 1 for each depth interval are presented in Appendix A. The SWACs for each section of Area 1 are listed in Table 1~~–2~~-2a. The SWAC values indicate that Section 3 should be the focus of additional statistical and geomorphologic evaluation to identify appropriate remedial alternatives. The Section 3 SWAC is relatively high compared to surrounding sections. The SWACs for Sections 2 and 4 are relatively low with SWAC concentrations less than 1 mg/kg in each interval; however, their upper confidence bounds (95%) are relatively higher and hot spots have been previously identified in these two sections Therefore, remedial alternatives for sediment hot spot areas in Sections 2 and 4 are developed in Section 3.0. The SWACs for all other sections and intervals were less than 1 mg/kg with the exception of Section 8. The SWAC for Section 8 was developed using primarily pre-Plainwell Dam removal data and ~~are~~is not representative of ~~actual~~present-day PCB SWACs in that section. Samples representing areas that were excavated in the TCRA were removed from the data set prior to SWAC calculation. Current PCB concentrations are likely much lower following the TCRA. Additional sampling for Section 8 will be performed as part of Area 1 remedial design to confirm current conditions in that part of the river. A separate SWAC was calculated for the Crown Vantage side channel (see Figure 1-2). SWAC values calculated for this area are 8.2, 21.2, and 21.0 mg/kg for the three depth intervals 0-6 inches, 6-12 inches, and 12-24 inches, respectively. Sediment remedial alternatives will be assembled to include the Crown Vantage channel based on these PCB SWACs and assume that USEPA will complete the current removal action in Portage Creek prior to implementation of the remedial alternative. Removal activities are scheduled to be completed in October 2013, depending upon weather/river conditions.

1.3.1.2 Floodplain Soil

Historical Sampling Events
Floodplain soil samples were collected in Area 1 during several investigation programs, beginning with the RI in 1993 and continuing through the SRI in 2010. The purpose of the floodplain soil investigation was to evaluate PCB deposition in formerly impounded areas, assess whether past flooding events transported PCBs to the floodplain, and characterize the nature and extent of PCB-impacted floodplain soil.

The initial floodplain investigation involved five Kalamazoo River floodplain sampling transects established between the confluence of Portage Creek and the city of Allegan. In addition to the five initial transects, six transects were sampled to characterize the nature and extent of PCB distribution within the boundaries of the former Plainwell Impoundment.

Investigations since 1993 (including the SRI) were performed to address data gaps and refine the understanding of the nature and extent of PCB contamination. One of the objectives of the SRI was to "characterize PCB concentrations in sediment, riverbanks, and floodplain soil near the Plainwell No. 2 Dam and Plainwell" (ARCADIS BBL 2007a). As part of the SRI, floodplain soil data were collected from floodplain areas within Area 1, including top-of-bank soil cores from Section 7, floodplain and adjacent soil sampling at the Crown Vantage landfill in Section 4, and the historically inundated area upstream of the Plainwell No. 2 Dam Area in Section 6. Most of the floodplain soil samples were collected near the Plainwell No. 2 Dams. Because several sampling locations were excavated as part of the two TCRAs completed in this area, the PCB data associated with those now removed locations are no longer representative of current conditions.

Distribution of PCBs in Floodplain Soil
The floodplain soil data have been grouped into four geographic subareas of Area 1. Each Area 1 floodplain Soil Area was identified as falling upstream, within, or between the two dam areas.

- Soil Area 1 is the reach from Morrow Dam to the railroad bridge at the upstream end of the Plainwell No. 2 Dam Area. Data include floodplain transect data, focused soil data within this reach, and the Crown Vantage soil data.
- Soil Area 2 is the Plainwell No. 2 Dam Area. Data include floodplain soil samples, bank samples, and soil samples that fall within this reach.
- Soil Area 3 is the area between the Plainwell No. 2 Dam and Main Street, Plainwell. Data include top-of-bank samples from along the river and the mill race.
- Soil Area 4 is the reach from Main Street, Plainwell to the former Plainwell Dam. Data include top-of-bank and floodplain soil samples.

The different characteristics of the four Area 1 soil areas influenced PCB concentrations in the floodplains. These divisions were established based on the premise that the dams had an important influence on depositional conditions. Where the river flow slowed through the impoundment behind the former Plainwell Dam and in the frequently-inundated area around the two flow control structures of Plainwell No. 2 Dam area, PCB-containing sediment tended to settle out of the water column. The resulting PCB concentrations in floodplain soil (including exposed former sediment in the former Plainwell Impoundment) in Soil Areas 2 and 4 are higher as compared to those in the natural floodplains surrounding the free-flowing sections of the river. Mean floodplain soil PCB concentrations in the Area 1 floodplain soil areas are summarized in Table 1-2b.

Table 1-2b Post-TCRA Mean PCB Concentrations by Floodplain Soil Area[1]

Soil Area	Mean PCB Concentration (mg/kg)[2]		
	Surface[3]	**Subsurface**	**All depths**
Soil Area 1:	0.76	0.30	0.46
Soil Area 2:	2.1	0.48	0.99
Soil Area 3:	1.6	2.0	1.9
Soil Area 4:	8.5	1.9	3.4

Notes:
1. Data set represents post-TCRA conditions.
2. Results rounded to two significant digits.
3. Average of surface intervals includes all samples with a depth interval starting at the ground surface

Source: ARCADIS 2012a, Table 6-33

PCB concentrations across sample depths of the floodplain are lower in Soil Area 1 than in the remaining Soil Areas. In Soil Area 1 with natural floodplains and no dams, the maximum (5.9 mg/kg), mean (0.46 mg/kg), and median (0.050 mg/kg) PCB concentrations are lower than in any other soil area.

Surface soil PCB concentrations are lowest in Soil Areas 1 and 3, which are those not directly influenced by dams. Maximum surface PCB concentrations in Soil Areas 1 and 3 are 5.8 mg/kg and 8.4 mg/kg, respectively, as compared to maximum surface soil values of 15 mg/kg in Soil Area 2 and 49 mg/kg in Soil Area 4. ~~Median~~Mean surface PCB concentrations follow a similar pattern, where the ~~median~~mean surface PCB concentrations in Soil Areas 1 and 3 (0.76 and 1.6 mg/kg, respectively)are lower than those found in Soil Areas 2 and 4~~.~~ (2.1 and 8.5 mg/kg, respectively).

The subsurface maximum soil PCB concentrations ranged from 5.9 mg/kg in Soil Area 1 to 79 mg/kg in Soil Area 4. ~~Median~~Mean soil PCB concentrations within the four Soil Areas ~~are less than 0.50 mg/kg, ranging~~range from 0.~~043~~46 mg/kg (Soil Area 1) to ~~0.27~~3.4 mg/kg (Soil Area 4). Higher PCB concentrations and frequency of detections occur downstream of the Plainwell No. 2 Dam Area in the top-of-bank samples (Soil Area 3) and in the former Plainwell Impoundment (Soil Area 4). ~~Median~~Mean PCB concentrations in Soil Areas 1 and 2 for subsurface samples are 0.~~043~~30 and 0.~~046~~48. mg/kg, respectively, while for downstream Soil Areas 3 and 4, the ~~median~~mean subsurface concentrations are 2.0~~.098~~ and ~~0.27~~1.9 mg/kg, respectively.

In the Plainwell No. 2 Dam Area (Soil Area 2), most of the elevated PCBs are found within the top 0.5 foot. In the Plainwell No. 2 Dam Area, the average thickness of PCB-containing soil is approximately 1.4 feet. In the former Plainwell Impoundment (Soil Area 4), PCB-containing soil is found at greater depths (approximately 1 foot to 3 feet). The average thickness of the PCB-containing layer in soil core samples in the former Plainwell Impoundment is approximately 3.4 feet (subject to uncertainty associated with depth of core penetration and recovery).

Exposed former sediment in the floodplains of the former Plainwell Impoundment and the Plainwell No. 2 Dam Area were the primary focus of the TCRAs completed in each area. The pre-TCRA soil PCB SWAC in the former Plainwell Impoundment and the Plainwell No. 2 Dam Area were 17 mg/kg and 3.2 mg/kg, respectively. Data representative of post-TCRA soil PCB levels indicate the current floodplain soil SWAC in the former Plainwell Impoundment is 6.6 mg/kg. In the Plainwell No. 2 Dam Area, the current post-removal SWAC is 2.4 mg/kg (see Section 6.3.4 of the Area 1 SRI Report [ARCADIS 2012a]).

The restored riverbanks and the clean soil placed over removal areas serve as a buffer in many locations between the river and the PCBs remaining in the exposed former sediment (i.e., materials that were underwater when the dam was fully operational but are now located in the floodplain). In both locations, the riverbanks and revegetated areas are monitored and maintained to provide erosion control.

Floodplain soil data show that flooding of the Kalamazoo River has not resulted in appreciable accumulation of PCBs in the natural floodplains (i.e., areas not influenced or inundated by the historical operations of dams) (ARCADIS 2012a). Targeted sampling performed in low-lying areas showed the average PCB concentration in the natural floodplain soil in Area 1 upstream of the railroad bridge on the upstream edge of the Plainwell No. 2 Dam Area is less than 1 mg/kg across sample depths and within the surface soil (0 to 6 inches). Additional details are provided in Section 6.3 of the USEPA-approved Area 1 SRI Report (ARCADIS 2012a).

Portage Creek floodplain soil with elevated PCB levels is being addressed as part of USEPA's ongoing TCRA. The estimated SWAC PCB concentration (top 6 inches) within the USEPA-delineated floodplain area targeted for removal is 24.1 mg/kg (polygon SA7, USEPA 2012). USEPA developed an RAL for soil with PCB concentrations of 10 mg/kg or greater, and established a post-removal cleanup goal of 5 mg/kg for soil to be confirmed by post-excavation sampling (USEPA 2011).

1.3.1.3 Fish Tissue Trends

Fish Trending Methodology

A Work Group consisting of USEPA, MDEQ, and Georgia-Pacific representatives convened weekly from April to early June 2013 to review fish tissue data applicability and data trending techniques. The information presented below reflects the results of this review.

Fish tissue samples from multiple species have been collected in Area 1 since the mid-1980s for analysis of total PCB concentrations. Smallmouth bass and common carp were chosen as the two representative species of fish for fish tissue trending. Smallmouth bass are an upper level predatory fish, which are muscular in nature with a low body fat content, whereas common carp are grazers near the bottom of the food chain and are a fatty fish. Fish tissues were analyzed for total PCB concentrations and percent lipids. The fish tissue analyses were based on the typical use of the fish. Carp tissue was analyzed as fillet with skin removed. Smallmouth bass tissue was processed two ways. Young-of-the year (YOY) smallmouth bass tissue was analyzed as whole-body composite samples. Adult smallmouth bass tissue was analyzed as fillet samples with the skin on. Smallmouth bass samples labeled as "fillet" were assumed to be skin-on because most of the smallmouth bass samples were analyzed with the skin. Carp samples labeled as "fillet" were assumed to be analyzed without skin because most of the carp were analyzed without the skin. In 1999 and 2009, split samples of fish were analyzed by two different laboratories. For consistency, concentrations analyzed by Northeast Analytical, Inc. (NEA) were chosen to represent concentrations in fish during these two years.

Fish were collected and analyzed in Area 1 over several years as presented below:

- Smallmouth bass fillet in 1985, 1993, 1997, 1999, 2000, 2001, 2006, 2009, and 2011

- Smallmouth bass YOY whole-body composite in 1999, 2000, 2001, 2006, 2009, and 2011
- Carp fillet in 1983, 1985, 1986, 1987, 1993, 1997, 1999, 2000, 2001, 2006, 2009, and 2011

Fish collected before 1986 were not retained in the datasets due to changes in laboratory methods for extracting and analyzing total PCBs as well as the age of the data. Samples were analyzed using at least one of two methods: reporting total congener PCBs and/or total Aroclor PCBs. Both of these analyses were reported in some cases. Total Aroclors were used to represent smallmouth bass fillet and carp fillet if both analyte results were available (Appendix Table B-1 and Table B-3). Total Congeners were used to represent smallmouth bass young of year whole body if both analyte results were available (Appendix Table B-2). The concentration differences between these two methods were minimal, although these two approaches measure PCBs differently. Samples with ND concentrations (i.e., concentrations were U flagged because the result was below detection limits) were included in the dataset as one-half the detection limit. The fillet tissue, both smallmouth bass and carp, were analyzed only for total Aroclors. The smallmouth bass young of year whole body were analyzed for total congeners. These were the only complete data sets available for each of these fish tissue types.

Fish lengths and percent lipid composition for each tissue type was compared across years. YOY samples collected in 1997 were nearly 50 percent longer than fish collected in other YOY sampling years. These samples were removed from the dataset because these samples are not comparable based on the length of the fish collected. Lengths for fillet samples were relatively similar so length normalization was not necessary. Percent lipids were highly variable across years.

Total PCB concentrations in fish tissue were adjusted for the lipid content of each fish sample by dividing total PCB concentration by the percent lipid of that sample. This results in PCB concentrations on a per lipid basis (i.e., mg total PCB/kg lipid). Trends of PCB concentrations in the three fish tissue combinations (i.e., smallmouth bass fillet, smallmouth bass YOY whole body, and carp fillet) were evaluated using these lipid-corrected PCB concentrations. Changes in lipid-corrected total PCB concentrations in fish over time were statistically evaluated using three different models: linear model, log-linear model (first order model), and mixed-order model. The mixed-order models, using Equation 5 in Stow et al. (1999), is an exponential decay model which allows the decay rate to be variable based on the data rather than pre-selected as occurs with the log-linear model. Mixed-order model regression cannot be directly calculated like a normal linear regression and must be calculated by an iterative process. Iterations are calculated until the model converges. Alternatively, if the acceptable number of iterations (i.e., 50) has been exceeded, the model is considered "not to converge" and no regression equation is generated. If the model converges, the model is considered valid for prediction of fish tissue concentrations over time.

Area 1 was split by two methods into five representative reaches to trend total PCB concentrations in fish over time. The three ABSA (ABSA-03, ABSA-04, and ABSA-05) were separated with the first method. ABSA-03 includes the Kalamazoo River from Morrow Lake Dam at the beginning of Area 1 to Mosel Avenue just outside Kalamazoo. This includes the sampling location near Kalamazoo Avenue designated ABSA-03.5. ABSA-04 starts at Mosel Avenue and ends at the Highway 131 Bridge upstream of the former Plainwell Dam. This includes sampling locations near D Avenue designated ABSA-04.5, Plainwell No. 2 Dam designated ABSA-04.6, and near Plainwell Impoundment Inlet designated ABSA-04.7. ABSA-05 extends from the Highway 131 Bridge to the end of Area 1 at the former Plainwell Dam. Area 1 was also split into Urban and Dams reaches. The Urban reach includes part of ABSA-03 starting at Kalamazoo Avenue to D Avenue near the middle of ABSA-04. The Dams reach includes the remaining portion of ABSA-04 (i.e., downstream of D Avenue) and ABSA-05. Statistical analyses were performed using the statistical package R (R Development Core Team, 2009). Datasets used for statistical analyses are included in Appendix B-1. Figures depicting data and regression models are included in Appendix B-2 through Appendix B-4.

Fish Trending Results

Lipid-corrected total PCB concentrations in smallmouth bass fillet have experienced statistically significant declines in ABSA-03, ABSA-05, and the Dam reach (Tables 1-3 and 1-4). Declines in these reaches range from 2.3 percent per year to 3.4 percent per year. The mixed-order model only converged for ABSA-03, at a 2 percent per year decline in total PCB concentrations. This value (2 percent per year) is therefore the minimum statistically meaningful fish tissue trend for this reach. The percent decrease of total PCB concentrations in smallmouth bass fillets in ABSA-05 and the Dams reaches is approximately equal to the decrease in carp fillet, indicating consistency in the decrease in total PCB concentrations in this reach of the river. For certain fish tissues/areas, a statistically meaningful trend was not observed, either because a trend is actually not evident or because insufficient data/highly variable data preclude a statistically meaningful analysis.

Lipid-corrected total PCB concentrations in smallmouth bass YOY whole-body composites have experienced statistically significant declines in ABSA-05 and the Dams reach (Tables 1-3 and 1-4). Statistically significant declines in these reaches are 7.7 percent per year and 7.5 percent per year, respectively. Two mixed-order models converged for YOY smallmouth, ABSA-03 and ABSA-05. The percent decline for ABSA-03 calculated from the mixed-order model indicated a 2.8 percent decrease per year. The percent decline for ABSA-05 calculated from the mixed-order model indicated a 10.4 percent decrease per year.

Lipid-corrected total PCB concentrations in carp fillet have significantly declined since the late 1980s (Table 1-3). Statistically significant declines in the different reaches range from 1.9 percent per year to 4.2 percent per year for the log-linear models (Table 1-4). The largest percent declines in total PCB concentrations were in ABSA-03 and the Dams reach while the lowest percent decline was in the Urban reach. Mixed-order models did not converge for carp, indicating that first order models are more appropriate to describe trends of PCBs in fish given the data.

Recent TCRA events around the Plainwell Dams contribute to the decrease in concentrations in the Dam reach. TCRA events in Portage Creek may contribute to the lower percent decline or lack of statistically significant decline in the Urban reach. Some models did not show a statistically significant trend for each reach of the river. Statistically significant percent declines ranged from 1.9 to 7.7 percent since 2006 for the first order models. Mixed-order models which converged showed percent declines ranging from 2.0 to 10.4 percent since 2006. Future estimates of fish tissue assuming no additional remedial actions will be based on a range of percent declines ranging from 0 to 7 percent with a focus on the range of 2 and 4 percent. The rates of decline of PCB concentrations in fish tissue are the result of several factors occurring simultaneously. These factors include, but are not limited to, removal actions, source control measures, changes in PCB load to Area 1, flood events, resuspension events, changes in fish habitat, and natural recovery processes. The rate of decline represents the collective effect of all these factors such that rates of decline solely due to natural recovery or other factors cannot be distinguished.

1.3.1.4 Surface Water

Completion of the TCRAs, continued decline of upstream contributions, and further reduction in loading of PCBs to the river from external sources have resulted in reductions in surface-water column PCB concentrations. The average PCB concentrations from 1994 to 2006–2010 declined in surface water within Area 1, with the highest reductions occurring between 1994 and 2000/2001. Recent data from 2011 long-term monitoring (LTM) activities indicate an average surface water concentration of 1.1 nanograms per liter (ng/L). In 2011, average water column PCB concentrations were highest at the Portage Creek outlet (5.0 ng/L) compared to average concentrations of 1.0 ng/L at the Morrow Dam outlet. Farther downstream, at the Main Street Bridge in Plainwell, average concentrations are 1.1 ng/L, similar to those flowing from Morrow Lake (ARCADIS 2012c).

1.3.2 Contaminant Fate and Transport

PCB Chemical Properties

The chemical properties of PCBs include low aqueous solubility, high hydrophobicity, high affinity for nonaqueous phases, high chemical stability, and low biodegradability. These properties influence the mode of transport and the ultimate fate of PCBs in the environment. PCBs are predominantly associated with fine-grained sediment particles in the aquatic systems, due to their hydrophobicity and high affinity to sorb to mineral surfaces and to partition into natural organic material. This association with sediment particles also makes sediment a "sink" for PCBs and, to a more limited extent, a reservoir supplying PCBs to the water column and biota within the aquatic ecosystem. As a result, the fate and transport of PCBs in the river are governed in part by the fate and transport of sediment in the river system.

Sediment Transport

An available sediment transport model for the Kalamazoo River (Syed et al. 2005) suggests that most of the river's sediment transport processes are in a state of dynamic equilibrium. Sediment in Area 1 are predominantly coarse-grained (approximately 80% are coarse and 20% are fine, as described in the Area 1 SRI Report – ARCADIS, 2012a). The degree of movement and locations of deposition and erosion depend on grain size of the sediment and on the magnitude and duration of flow events. Generally, finer-grained, uncompacted materials are more easily transported than coarse-grained sediment. There are no extensive areas of long-term accretion of large amounts of sediment. The same was not true historically when the lake-like impoundment created by the Plainwell Dam trapped sediment behind the dam. With the removal of the dam, that portion of Area 1 will establish a new dynamic equilibrium between erosion and deposition processes.

An important distinction regarding sediment transport processes is that between cohesive and non-cohesive sediment. Coarse grains, such as sands and gravel, are non-cohesive and tend to erode from the channel bed, banks, and floodplains as individual particles. In general, finer-grained sediment (primarily composed of silt and clay) can become more cohesive than coarser-grained sediment when compacted. As particle size decreases, the amount of total surface area among particles increases, and the inter-particle forces dominate the behavior of sediment. Fine-grained particles of clay and silt can flocculate to form discrete, larger silt-sized and even sand-sized particles that can deposit on the riverbed. These sediment can compact and consolidate over time, forming a sediment bed or riverbank that behaves and erodes differently than non-cohesive sediment. The interaction of organic content, suspended sediment concentration and turbulence that ultimately determine the size of individual flocs is complex; however, it is important to recognize this process. In particular, greater scour force would be required to remobilize cohesively formed deposits than conditions under which the materials are deposited. Cohesive sediment are of interest in many rivers because they are composed of fine-grained particles, and many chemical constituents, such as metals, pesticides, and PCBs, preferentially adsorb to such particles.

Along the Kalamazoo River, the effects of channel morphology are evident in localized areas where PCBs have accumulated in relatively thicker sediment deposits along the channel margins or in point bars on the inside of channel curves where velocities are slower. Woody debris in the river and other impediments to flow in shallower water along the banks would also contribute to finer-grained sediment occurring along the channel margins.

Bank Erosion

River channels, riverbanks, and floodplains exchange sediment as materials are transported from headwaters downstream through an alluvial valley. During this process, banks tend to erode during floods and accumulate sediment as a point bars during low and moderate flows. In sinuous and meandering streams, bank erosion is most often focused on the outside of a meander bend with the eroded sediment from one bank typically being deposited downstream, on the inside of the meander bend to form a point bar. In Area 1, most of the river is a single-threaded, sandy-bottomed channel with low to moderate sinuosity, moderate to high width-to-depth ratios, and narrow floodplain, all of which limit meandering and channel migrations, and therefore, bank erosion. Visual reconnaissance through most of Area 1 performed in June 2013 indicated that the majority of riverbanks are gently sloped and well-vegetated with little evidence of bank erosion except in limited locations where development has encroached on the river. Photographic documentation of riverbank conditions is provided in Appendix C.

Historically, it has been recognized that the most important sources of PCBs for downstream transport are associated with erosion of PCB-containing paper residues and soil in exposed banks in the former impoundments and dam areas. Within Area 1, these sources have been predominantly controlled with the implementation of the TCRAs in the former Plainwell Impoundment and Plainwell No. 2 Dam Area. An evaluation and monitoring of potential erosion from banks containing PCBs in Area 1 will be included in remedial alternatives. There is the potential for unremediated bank and floodplain soil to contribute PCBs to the river with other continuing low-level sources.

Floodplains

River-floodplain interactions govern the extent to which PCBs in the river influence floodplain soil PCB concentrations. In sections of the river that were historically influenced by dams, PCB levels in floodplain soil are higher than in the more natural floodplain areas where inundation has occurred much less frequently and for shorter duration. PCB impacts to natural floodplain soil are significantly less than within the formerly impounded or inundated areas (ARCADIS 2012a).

Impacted floodplain soil potentially serve as depositional areas for PCBs that are delivered during periods of flooding and that would reenter the river through surface runoff erosion processes. Given the generally flat topography and well-vegetated state of most of the floodplain in Area 1, mobilization of floodplain soil via erosion into the river is not expected to be a major transport mechanism.

Fish Tissue

Risks to human health (CDM 2003b) and aquatic ecological receptors (CDM 2003a) are driven by the consumption of fish. Human health risk estimates show concentrations of PCBs in fish tissue result in exceedances of USEPA target levels for both cancer and noncancer risks. PCB levels in fish are linked to concentrations in sediment through the food chain.

Following control of external paper industry-related sources of PCBs in Area 1, remaining external PCB sources and fate and transport of PCBs within Area 1 will govern the bioavailability of PCBs to fish in the future. As external sources are controlled, fate and transport processes internal to Area 1 with habitat and biological factors will govern the extent and temporal response of PCB levels in fish tissue. External sources of PCBs to Area 1 are expected to sustain low levels of PCBs in fish tissue in the long-term, even with control of known potential source areas associated with historical papermaking operations.

1.3.3 Risk Assessment Summary

1.3.3.1 Baseline Human Health Risk Assessment Summary

The Baseline Human Health Risk Assessment (BHHRA) for the Site was completed by CDM in May 2003 (CDM, 2003b). The BHHRA evaluated potential current and future risks to people who may live or engage in recreational activities near the Kalamazoo River and its floodplain. The BHHRA was performed for all seven areas of OU5 (Figure 1-1).

The BHHRA evaluated risks to subsistence and sport anglers who may consume fish caught from each of 12 ABSAs identified on the Kalamazoo River (Figure 1-3 shows the ABSAs relative to Area 1). Nine ABSAs were considered exposure areas in which fish would have contact with Site-related PCBs (ABSAs 3 through 11). Two ABSAs (ABSA 1 and ABSA 2) are located upstream of known sources associated with the API/PC/KR site and serve as reference areas for PCB contamination in fish tissues. ABSA 12 is located in Portage Creek and was not included in the BHHRA. Data from three ABSAs (ABSAs 3, 4, and 5) encompassing the area between the Morrow Dam and the former Plainwell Dam were combined by CDM to represent exposure for Area 1, while the other six ABSAs were each evaluated as a discrete exposure area.

ARCADIS updated the BHHRA (CDM 2003b) in 2012 as part of the SRI (ARCADIS, 2012a). MDEQ and Georgia-Pacific have collected additional fish tissue samples since the publication of the 2003 BHRRA. Risk estimates for anglers were updated based on recent detected PCB concentrations in fish tissue.

The updated BHHRA estimated risks and hazards for two populations of anglers: a sport angler and a subsistence angler. Risks and hazards were associated with exposures to PCBs released into the Kalamazoo River system. In addition to fish consumption by anglers, several other potential exposure pathways were described in the 2003 BHHRA and are relevant to Area 1. These potential human health exposure pathways and associated conclusions, which are based on either CDM (2003b) or the Michigan Department of Community Health of the State of Michigan (MDCH) Health Consultation, are summarized below.

- *Consumption of turtles:* Although this pathway was evaluated qualitatively by CDM (2003b) as a potential exposure pathway, CDM concluded that the overall exposure and risks by receptors ingesting turtles would be less than that of anglers. The analytical data that exist for turtle tissue (ABSAs 5 and 10) indicate that PCB concentrations are less than that for smallmouth bass and carp fish tissue.
- *Consumption of waterfowl*: This exposure pathway was considered by CDM (2003b). However, because of data limitations with waterfowl samples, CDM did not quantify risk estimates and did not complete a qualitative evaluation.

- *Direct contact with river sediment (by swimmers or waders):* Direct contact exposures to river sediment during recreational activities (swimming, wading) were determined not to be important means of exposure to PCBs based on an evaluation prepared by the MDCH, and were not evaluated further in the CDM (2003b) BHHRA.
- *Exposure to in-stream surface water (by swimmers or waders):* These exposures were considered by CDM (2003b) to be low due to the relatively low ingestion rates of surface water, the low solubility of PCBs in water, and the low dermal absorption of PCBs. Therefore, CDM (2003b) concluded that this pathway could be assumed to be without risk.
- *Exposure to air:* Inhalation of particulates and volatile emissions from exposed floodplain soil and sediment were quantitatively evaluated in the CDM (2003b) BHHRA as part of the evaluation of direct contact pathways with floodplain soil and exposed sediment (see above). CDM did not conduct a quantitative risk evaluation for the inhalation of volatile emissions from surface water.
- *Direct contact with floodplain soil and exposed sediment:* These direct contact pathways may be relevant to either residents (the most highly exposed receptor group) or recreational visitors to the floodplain areas or the river, and these pathways, involving dermal contact with and incidental ingestion of floodplain soil and exposed sediment, were quantitatively evaluated in the CDM (2003b) BHHRA. Inhalation of particulates and volatile emissions from floodplain soil and exposed sediment were also quantitatively evaluated in the BHHRA. Residential developments exist next to the floodplains in three areas (the former Plainwell, Otsego, and Trowbridge Impoundments), with no restrictions in accessing the floodplain soil. The floodplain area next to the former Plainwell dam is the only soil exposure area included in Area 1.

Fish Advisory
MDCH issued a fish advisory for parts of the Kalamazoo River extending from Morrow Lake Dam to Lake Michigan (MDCH 2010). The advisory, from Morrow Lake Dam to the Allegan Dam and on Portage Creek downstream of Monarch Mill Pond, recommends that the general population not consume carp, catfish, suckers, smallmouth bass, and largemouth bass on the Kalamazoo River. Between Allegan Dam and Lake Michigan, the advisory recommends that the general public not consume carp, catfish or northern pike. Healthy adult males are advised to eat no more than one meal per week of all other species. For women of childbearing age and children under 15 years of age, no consumption of any species is recommended for fish caught above Allegan Dam (including Area 1). The fish consumption advisory issued by MDCH is only a recommendation, is not legally binding, and has limited effectiveness in protecting human health. A 1994 survey of anglers on the Kalamazoo River conducted by MDCH reported that anglers from Kalamazoo and Allegan Counties ate on average two meals per month of various species including bass, catfish, panfish, bullheads, and carp taken from contaminated reaches of the river. More than 10 percent of anglers ate more than one meal per week of these various species. This survey confirmed that the Kalamazoo River is an important recreational resource and may serve as an important source of food for certain subpopulations.

Data Evaluation
Fish tissue data collected in 2009 were included in the risk assessment data set for anglers. Although, data for multiple species of fish were included in the 2003 BHHRA, only two species, smallmouth bass and carp, were selected to represent a popular pelagic sport fish and a bottom-feeding fish in the risk calculations. The fish tissue data collected in 2009 included PCB concentrations for rock bass, sunfishes, bullheads, and channel catfish in addition to the

species evaluated in the 2003 BHHRA However, risks were updated using the 2009 data for smallmouth bass and carp only to be consistent with the 2003 BHHRA. A separate, secondary analysis of the 2009 data was also performed, which included PCB concentrations for the additional species in the fish data set. This assessment was conducted to provide information on PCB levels and risks in other species targeted by anglers, based on the information from angler surveys. Fish tissue data included skin-off fillet data for carp and skin-on fillet data for smallmouth bass. Fillet data was used in the BHHRA because these data best represent the edible portions of fish prepared and consumed by anglers. Individual Aroclors in fish tissue samples were analyzed; however, the BHHRA was based on total PCBs, as recommended by USEPA.

Floodplain surface soil data presented in the 2003 BHHRA near the former Plainwell, Otsego, and Trowbridge Dams were used to assess risk from floodplain soil to residents and recreational receptors. While these dams impounded water, PCB-contaminated sediment was deposited in the impoundments. When the Plainwell Dam at the downstream end of Area 1 was initially lowered to the sill by the DNR in the 1980s and then later removed as part of the TCRA described above, the water level was lowered, and former contaminated sediment deposits were exposed in the floodplain. The Plainwell Dam removal and sediment/soil TCRA lowered the overall PCB concentrations in Sections 7 and 8. However, risk estimates to floodplain soil exposures were not updated as part of the 2012 SRI.

Exposure Assessment
The final list of receptors and exposure pathways quantitatively evaluated for the site include:

- Sport anglers – fish ingestion
- Subsistence anglers – fish ingestion
- Residents living next to exposed floodplain soil – incidental ingestion of, dermal contact with, and inhalation of particles and the volatile fractions of floodplain soil
- Recreationists exposed to floodplain soil – incidental ingestion of, dermal contact with, and inhalation of particles and the volatile fractions of floodplain soil

Two key studies of fish ingestion behaviors of anglers in the Great Lakes region were used to estimate the percentage of fish species ingested and the ingestion rates included in the HHRA (West 1989, 1993). Using data from these studies, two scenarios were evaluated for both sport and subsistence anglers: 1) ingestion of 100 percent smallmouth bass; and 2) ingestion of a combination of 76 percent smallmouth bass and 24 percent carp. For the first scenario, exposure concentrations were based solely on smallmouth bass data collected from the Site. For the second scenario, a combination of smallmouth bass and carp data were used. Total ingestion rates were apportioned across the two species accordingly. Risk characterization for sport anglers was further evaluated using two separate ingestion rates: 1) central tendency (i.e., 0.015 kilogram per day (kg/day) or 24 half-pound meals/year); and 2) high end (i.e., 0.078 kg/day or 125 half-pound meals/year). The central tendency ingestion rate is the mean ingestion value for sport anglers in the Great Lakes Basin and is the 90th percentile for the overall population in the Great Lakes Basin (West 1989, 1993), Wisconsin (Fiore, et al. 1989), and New York (Connelly, et al. 1990). This fish ingestion rate has been used by the MDEQ Surface Water Quality Division to establish surface water quality standards for ingestion of fish. The high-end ingestion rate for sport anglers is based on the 95th percentile ingestion values (West 1989, 1993) for non-minority low-income anglers. A fish ingestion rate of 0.11 kg/day or 179 half-pound meals/year was used for subsistence anglers based on the 95th percentile ingestion rates (West 1989, 1993) for minority low-income anglers.

The exposure point concentration (EPC) of PCBs in fish tissue was estimated by calculating the 95 percent upper confidence limit of the mean (95% UCL) concentration. The 95% UCL was determined using USEPA's ProUCL statistical software (Version 4.1). The 95% UCL was used as the EPC for the high-end analysis, and the arithmetic mean was used as the EPC for the central tendency analysis. Similarly, when it was assumed that individuals consume 76% smallmouth bass and 24% carp, the 95% UCL values, calculated separately for the smallmouth bass and the carp, were combined in a weighted average (76% assumed to have the 95% UCL concentration in smallmouth bass and 24% assumed to have the 95% UCL concentration for carp) to derive a high-end EPC. The arithmetic means for each species group were similarly combined in a weighted average to derive the central tendency EPC.

For each of the three exposure scenarios (high-end sports angler, central tendency sports angler, and subsistence angler), four scenarios were used in the updated risk calculations:

1. 100% of the fish consumed were smallmouth bass and the arithmetic mean PCB concentration for smallmouth bass was used as the EPC
2. 100% of the fish consumed were smallmouth bass, and the 95% UCL PCB concentration was used as the EPC
3. 76% of the fish consumed were smallmouth bass and 24% were carp and, for each group, the arithmetic mean PCB concentration was used as the EPC
4. 76% of the fish consumed were smallmouth bass and 24% were carp and, for each group, the 95% UCL PCB concentration was used as the EPC

Toxicity Assessment
In the toxicity assessment, the potential health effects of PCBs were evaluated and toxicological benchmarks were identified to quantify cancer risks and noncancer hazards. The potential health effects of PCBs include cancer, reproductive effects, and immunological effects.

Risk Characterization
The risk characterization step of the BHHRA combined information from the data evaluation, toxicity assessment, and exposure assessment to develop estimates of cancer risks and noncancer hazards. Excess cancer risks are expressed as a probability of an individual developing cancer from site-related exposures. Cumulative noncancer risk is expressed as a hazard index (HI), which is a ratio of the estimated dose of PCBs received from an exposure to a reference dose (RfD), which is the dose below which adverse health effects are not expected to occur. In the BHHRA, two noncancer endpoints were evaluated: reproductive health effects and immunological health effects. USEPA has established a generally acceptable target range for carcinogenic risk of 1 in 1,000,000 (1×10^{-6}) to 1 in 10,000 (1×10^{-4}); The MDEQ considers risk less than 1 in 100,000 (1×10^{-5}) to be acceptable. Both USEPA and MDEQ consider hazard quotients (HQs) and HIs at or less than 1 to be acceptable. The following report sections summarize the estimated risks and hazards for each receptor group.

Results of the Updated Risk Analysis for Anglers
Central tendency Sport Anglers: Carcinogenic risks in Area 1 were within USEPA's acceptable risk range for specific receptor scenarios (100% smallmouth bass diet with 50% of the fish from the

Kalamazoo River) of 1×10^{-6} to 1×10^{-4}, but were greater than the MDEQ target of 1×10^{-5} regardless of the EPC used or the fish consumption scenario evaluated.

Table 1-5. Summary of Carcinogenic Risks for the Central Tendency Angler (95% UCL EPC)

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	7E-06	2E-05
ABSA 2 ~~(Reference)~~ Morrow Lake	3E-05	~~4E~~5E-05
ABSA 4&5	7E-05	2E-04
ABSA 4	4E-05	2E-04
ABSA 5	1E-04	3E-04

Table 1-6. Summary of Carcinogenic Risks for the Central Tendency Angler (Mean EPC)

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	3E-06	7E-06
ABSA 2 ~~(Reference)~~ Morrow Lake	2E-05	~~3E~~2E-05
ABSA 4&5	4E-05	2E-04
ABSA 4	3E-05	1E-04
ABSA 5	8E-05	2E-04

Reproductive hazards using the 95% UCL as an EPC resulted in Area 1 HQs greater than the target of 1 in ABSA 5 assuming the consumption of 100% smallmouth bass, and HQs greater than the target of 1 in ABSA 4&5, ABSA 4, and ABSA 5 assuming the consumption of a mixture of species. Using an EPC equal to the arithmetic mean, HQs in Area 1 were within the target of 1 for ABSAs 4 and 5 assuming the consumption of 100% smallmouth bass. HQs, when based on the consumption of a mixture of species, were greater than the target of 1 in ABSAs 4 and 5.

Immunological hazards, regardless of EPC used, resulted in Area 1 HQs greater than the target of 1.

Table 1-7. Summary of Hazards for the Central Tendency Angler (95% UCL EPC) – Reproductive

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.1	0.3
ABSA 2 ~~(Reference)~~ Morrow Lake	0.5	0.~~6~~9
ABSA 4&5	1	4
ABSA 4	0.6	3
ABSA 5	2	5

Table 1-8. Summary of Hazards Risks for the Central Tendency Angler (Mean EPC) – Reproductive

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.05	0.1
ABSA 2~~ (Reference) ~~ Morrow Lake	0.3	0.4
ABSA 4&5	0.7	3
ABSA 4	0.5	2
ABSA 5	1	3

Table 1-9. Summary of Hazards for the Central Tendency Angler (95% UCL EPC) – Immunological

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.4	1
ABSA 2~~ (Reference) ~~ Morrow Lake	2	~~2~~3
ABSA 4&5	4	12
ABSA 4	2	10
ABSA 5	7	17

Table 1-10. Summary of Hazards Risks for the Central Tendency Angler (Mean EPC) - Immunological

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.2	0.4
ABSA 2~~ (Reference) ~~ Morrow Lake	1	1
ABSA 4&5	3	9
ABSA 4	2	8
ABSA 5	5	12

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Subsistence Anglers: Carcinogenic risks in Area 1 were greater USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4}, and greater than the MDEQ target of 1×10^{-5} in ABSAs 4 and 5 regardless of the EPC used or the fish consumption scenario evaluated.

Table 1-11. Summary of Carcinogenic Risks for the Subsistence Angler (95% UCL EPC)

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	5E-05	1E-04
ABSA 2~~ (Reference) ~~ Morrow Lake	2E-04	~~3E~~4E-04
ABSA 4&5	5E-04	2E-03
ABSA 4	3E-04	1E-03
ABSA 5	9E-04	2E-03

Table 1-12. Summary of Carcinogenic Risks for the Subsistence Angler (Mean EPC)

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	2E-05	5E-05
ABSA 2 ~~(Reference)~~ Morrow Lake	1E-04	2E-04
ABSA 4&5	3E-04	1E-03
ABSA 4	2E-04	1E-03
ABSA 5	6E-04	1E-03

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Reproductive and immunological hazards in Area 1 were indicated by HQs greater than the target of 1 in ABSAs 4 and 5 and under both EPCs and ~~under~~ both fish consumption scenarios.

Table 1-13. Summary of Hazards for the Subsistence Angler (95% UCL EPC) - Reproductive

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.8	2
ABSA 2 ~~(Reference)~~ Morrow Lake	~~3~~4	~~4~~7
ABSA 4&5	9	26
ABSA 4	4	21
ABSA 5	15	35

Table 1-14. Summary of Hazards Risks for the Subsistence Angler (Mean EPC) - Reproductive

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.4	0.9
ABSA 2 ~~(Reference)~~ Morrow Lake	2	3
ABSA 4&5	5	19
ABSA 4	4	17
ABSA 5	10	25

Table 1-15. Summary of Hazards for the Subsistence Angler (95% UCL EPC) - Immunological

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	3	9
ABSA 2 ~~(Reference)~~ Morrow Lake	~~12~~13	~~15~~23
ABSA 4&5	30	90
ABSA 4	15	74
ABSA 5	52	123

Table 1-16. Summary of Hazards Risks for the Subsistence Angler (Mean EPC) - Immunological

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	1	3
ABSA 2 ~~(Reference)~~ Morrow Lake	8	11
ABSA 4&5	18	68
ABSA 4	13	61
ABSA 5	35	87

High-end Sports Angler: For the high-end sport angler scenario, cancer risk estimates and HQs fall between the results for the subsistence angler and central tendency sport angler. Assuming a 100% smallmouth bass consumption scenario, carcinogenic risks in Area 1 were greater than USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4} and the MDEQ target of 1×10^{-5} in two exposure areas (ABSA 5 and ABSA 4 and 5) regardless of the EPC assumed. Assuming a mixed species consumption scenario, carcinogenic risks in Area 1 were greater than USEPA's acceptable risk range of 1×10^{-6} to 1×10^{-4} and the MDEQ target of 1×10^{-5} in all three exposure areas evaluated for Area 1.

Table 1-17. Summary of Carcinogenic Risks for the ~~Central Tendency~~High-End Sports Angler (95% UCL EPC)

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA ~~2 (Reference)~~1-Ceresco Reservoir	~~7E~~2E-05	~~9E~~5E-05
ABSA 2-Morrow Lake	8E-05	1E-04
ABSA 4&5	2E-04	5E-04
ABSA 4	9E-05	4E-04
ABSA 5	3E-04	7E-04

Table 1-18. Summary of Carcinogenic Risks for the ~~Central Tendency~~High-End Sports Angler (Mean EPC)

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	7E-06	2E-05
ABSA 2 ~~(Reference)~~ Morrow Lake	5E-05	~~7E~~6E-05
ABSA 4&5	1E-04	4E-04
ABSA 4	8E-05	4E-04
ABSA 5	2E-04	5E-04

Reproductive and immunological hazards were potentially indicated by HQs greater than the target of 1 in the three exposure areas of Area 1 using both the 95% UCL concentration and the mean concentration and under both fish consumption scenarios.

Table 1-19. Summary of Hazards for the High-End Sports Angler (95% UCL EPC) - Reproductive

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.3	0.9
ABSA 2 ~~(Reference)~~-Morrow Lake	1	2
ABSA 4&5	3	9
ABSA 4	2	7
ABSA 5	5	12

Table 1-20. Summary of Hazards Risks for the High-End Sports Angler (Mean EPC) - Reproductive

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA ~~2 (Reference)~~1-Ceresco Reservoir	0.~~9~~1	~~1~~0.3
ABSA 2-Morrow Lake	0.8	1
ABSA 4&5	2	7
ABSA 4	1	6
ABSA 5	4	9

Table 1-21. Summary of Hazards for the High-End Sports Angler (95% UCL EPC) - Immunological

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	1	3
ABSA 2 ~~(Reference)~~-Morrow Lake	~~4~~5	~~5~~8
ABSA 4&5	11	32
ABSA 4	5	26
ABSA 5	18	44

Table 1-22. Summary of Hazards Risks for the High-End Sports Angler (Mean EPC) - Immunological

Exposure Point	100% Smallmouth Bass	76% Smallmouth Bass/ 24% Carp
ABSA 1-Ceresco Reservoir	0.4	1
ABSA 2 ~~(Reference)~~-Morrow Lake	3	4
ABSA 4&5	7	24
ABSA 4	5	22
ABSA 5	12	31

Secondary Risk Analysis for Anglers

A secondary risk assessment was conducted for anglers who were opportunistic and ate a variety of species of fish. Specifically, it was assumed that individuals might consume any species for which 2009 data were available for fish greater than or equal to 8 inches in length. In this secondary analysis, fish species for which relevant 2009 data (i.e., from samples that meet the length criterion) were available were grouped into one of two categories: 1) pelagic feeders, which included smallmouth bass and rock bass, and 2) bottom-feeders, which included carp, bullheads, and channel catfish. It was assumed that anglers either consumed 100% pelagic fish or 76% pelagic fish and 24% bottom-feeders, to be consistent with the primary risk analysis performed for anglers.

All fish samples were given equal weight in the EPC calculation (i.e., they were not weighted by species preference or by numbers of samples available for each species) and, therefore, the EPCs reflect the numbers of fish collected in each ABSA during 2009. For each ABSA, EPCs were calculated using 95%UCL concentrations for each fish category. Arithmetic average concentrations were also calculated to be consistent with CDM's approach, as previously described.

The cancer risk estimates and HQs resulting from this secondary analysis of the consumption of pelagic and bottom-feeding species are similar to, or slightly lower than, the updated risks and hazards discussed above, which were based on the use of data for smallmouth bass and carp only.

Risks and Hazards for Residents and Recreationists Exposed to Floodplain Soil
Risks to floodplain soil exposures to residents and recreationists next to the areas near the former Plainwell, Otsego, and Trowbridge Impoundments (the western end of Areas 1, 2, and 4; see Figure 1-1) were assessed using both average surface soil PCB concentrations and maximum PCB concentrations (insufficient data was available to calculate a 95% UCL concentration for PCBs in surface soil).

Using average floodplain soil concentrations, cancer risks to residents in all three floodplain soil areas were within the USEPA target cancer risk range of 1×10^{-6} to 1×10^{-4}, but above the MDEQ cancer risk threshold of 1×10^{-5}. Using maximum floodplain soil concentrations, cancer risks were greater than the USEPA target cancer risk range and exceeded the MDEQ threshold.

Using both average and maximum floodplain soil concentrations, HIs based on immunological endpoints for residents in all three floodplain soil areas exceeded the USEPA and MDEQ HI threshold of 1. For residential receptors exposed via multiple routes (i.e., ingestion, dermal contact, and inhalation of fugitive dust) to floodplain soil, HIs for the reproductive endpoint exceeded 1 using maximum concentrations for all three areas. HIs for the reproductive endpoint using average floodplain soil concentrations did not exceed 1.

Using average floodplain soil concentrations, cancer risks to recreationists in all three floodplain areas were within the USEPA target risk range and less than the MDEQ cancer risk threshold. Using maximum floodplain soil concentrations, cancer risks were within the USEPA target risk range, but greater than the MDEQ cancer risk threshold. The highest cancer risk using maximum concentrations was estimated for the Plainwell area where cancer risks were 4 in 100,000.

Using average floodplain soil concentrations, HIs to recreationists based on both the immunological and reproductive endpoints were less than the USEPA and MDEQ threshold of 1.0. Using maximum concentrations, HIs based on the immunological endpoint exceeded the USEPA and MDEQ threshold for the Plainwell (2.7), Otsego (1.1) and Trowbridge (2.5) areas. Using maximum concentrations, HIs based on the reproductive endpoint were all less than the hazard index threshold.

BHHRA Conclusions
The BHHRA for the Site and Area 1 presented estimated cancer risks and noncancer hazards for several populations of anglers consuming fish from the Kalamazoo River, and residential and recreational receptors exposed to floodplain soil adjacent to the former Plainwell, Otsego, and Trowbridge Impoundments.

Risk characterization for anglers was performed for three potential populations: 1) central tendency sports angler consuming an average of 0.015 kg fish tissue/day (24 half-pound meals/year); 2) high-end sports angler consuming 0.078 kg fish tissue /day (125 half-pound meals/year); and, 3) subsistence anglers consuming 0.11 kg fish tissue/day (179 half-pound meals/year). Two exposure scenarios for the three angler populations were included in the BHHRA. In the first scenario, a diet of 100 percent pelagic fish species was assumed. The second scenario assumed a mixed species diet (76 percent pelagic species and 24 percent bottom-feeding species). Both the 95%UCL of the mean PCB concentration and the arithmetic mean were used as EPCs for fish tissue.

Regardless of the specific angler population or EPC used to calculate risk, potential excess cancer risks and noncancer hazards exceeded acceptable levels for the fish ingestion pathway. Cancer risks were 2×10^{-3} for the subsistence angler. In addition, the subsistence angler also had the highest estimated HI of 123. Adverse health effects associated with PCB exposure include increased risk of liver cancers and reproductive and immunological impairment. The highest risks and hazards are associated with a mixed species diet, and were highest in ABSA 5. ABSA 5 is located in the vicinity of the recent TCRAs and the BHRRA does not take into account recent reductions of PCB concentrations in sediment and soil.

Excess cancer risks and noncancer hazards estimated for residents and recreationists potentially exposed to floodplain surface soil are based on pre- TCRA concentrations, and thus overestimate risks and hazards under current and future conditions. For the three areas evaluated (i.e., the former Plainwell, Otsego, and Trowbridge Dams), estimated risks for residents exposed to average floodplain surface soil concentrations were within the USEPA target cancer risk range of 1×10^{-6} to 1×10^{-4}, but were greater than the MDEQ cancer risk threshold of 1×10^{-5}. Excess cancer risk estimates exceed the acceptable risk range when the maximum detected concentration for each area was used as the EPC. For residential receptors exposed via multiple routes (i.e., ingestion, dermal contact, and inhalation of fugitive dust) to floodplain soil, HIs for the reproductive endpoint exceeded 1 using maximum concentrations for all three areas. HIs for the reproductive endpoint using average floodplain soil concentrations did not exceed 1. Using both average and maximum floodplain soil concentrations, HIs based on immunological endpoints for residents in all three floodplain soil areas exceeded the USEPA and MDEQ hazard index threshold of 1.

Excess cancer risks and noncancer hazards for recreationists exposed to average floodplain surface soil concentrations were within the USEPA target cancer risk range of 1×10^{-6} to 1×10^{-4}, and less than the MDEQ cancer risk threshold of 1×10^{-5} in the three areas evaluated (i.e., the former Plainwell, Otsego, and Trowbridge Dams). Potential cancer risks were within the USEPA target risk range, but greater than the MDEQ cancer risk threshold if the maximum floodplain soil concentration was used as the EPC in each area. Noncancer health effects were not indicated for this receptor (i.e., HQs were less than 1) using an average PCB soil concentration; however, potential adverse health effects were indicated using a maximum PCB soil concentration. USEPA and MDEQ have instituted fish advisories for the consumption of fish based on the risk assessment results. There are no restrictions for human health associated with exposure to sediment, soil, or surface water.

In summary, unacceptable risks and hazards were associated with the fish ingestion pathway, but unacceptable risks and hazards for residents and recreationists were also associated with potential exposure to maximum floodplain soil concentrations. Assumptions were made using best professional judgment and the scientific literature on site risk assessments. In general, assumptions made throughout this risk assessment were conservative in that they tend to overestimate exposure and resultant risk rather than underestimate it. In particular, the risk assessment for floodplain surface soil was based on pre-TCRA soil concentrations and would tend to overestimate current and future risks for residents and recreationists. The overall risk to public health attributable to Area 1 is an upper-bound probability of adverse health effects. True health effects may be lower. The highest risks based on the floodplain soil pathways are 2- and 25-fold lower than those for the central tendency sports angler and subsistence angler scenarios, respectively.

1.3.3.2 Baseline Ecological Risk Assessment

On behalf of MDEQ, CDM prepared a Site-Wide (OU-5) Baseline Ecological Risk Assessment (BERA) (CDM, 2003a) that identified terrestrial and aquatic receptors and exposure pathways. An updated Area 1 Terrestrial Baseline Ecological Risk Assessment (TBERA) for terrestrial birds and mammals was conducted and included as Appendix B to the USEPA-approved Area 1 SRI Report (ARCADIS, 2012a). The methods and approaches incorporated in the Area 1 TBERA built on the information in the Site-Wide BERA (CDM, 2003a) and the USEPA-approved *Generalized Conceptual Site Model* (CSM Report; ARCADIS, 2009). The Area 1 TBERA methods and approaches also accounted for updated risk assessment guidance and scientific research, additional sampling conducted at the Site, two TCRAs completed in Area 1, and source control activities completed or underway at the former mill properties and landfill OU areas in Area 1 since the Site-Wide BERA was completed. The removal and source control actions changed exposure concentrations of PCBs in environmental media in Area 1 compared to those reflected in the Site-Wide BERA. The ecological dataset for the Area 1 TBERA analyses reflected conditions after completion of the two TCRAs and incorporated the results from post-removal sampling events. The Area 1 TBERA did not revisit the aquatic portion of the Site-Wide BERA. The Site-Wide BERA conclusions for aquatic receptors were carried forward in the Area 1 TBERA. The following report sections summarize the results of the Site-Wide BERA and the Area 1 TBERA.

1.3.3.3 Summary of Site-Wide BERA

The Site-Wide BERA (CDM, 2003a) was conducted to evaluate potential ecological effects to terrestrial and aquatic receptors associated with PCB exposures in surface water, sediment, surface soil, and biota. Representative ecological receptors included aquatic plants, aquatic macroinvertebrates, game fish, forage fish, rough fish, terrestrial invertebrates, small burrowing omnivorous mammals, semi-aquatic herbivorous mammals, small semi-aquatic carnivorous mammals, and top mammalian and avian predators. The Site-Wide BERA evaluated complete exposure pathways that included the following:

- Surface water – direct contact, uptake, ingestion, or ingestion of prey
- In-stream sediment/interstitial water – direct contact, ingestion, or ingestion of prey
- Surface soil/floodplain sediment and soil – direct contact, ingestion, or ingestion of vegetation/prey

Risk estimates were based on the Site-wide 95% UCL on the arithmetic mean total PCB concentrations for abiotic media and fish. For food chain modeling, maximum total PCB concentrations for sampled terrestrial biota (i.e., earthworms, mice, and muskrat) were used.

No observed adverse effects level (NOAEL) and lowest observed adverse effects level (LOAEL)-based HQs indicated the highest potential for risk for piscivorous mammals, represented by the mink. For terrestrial species, vermivorous birds, represented by the American robin, had the highest potential for risk. Based on the calculated NOAEL-based HQs, risk for minks is highest, followed by the bald eagle, the great horned owl, the American robin, and the red fox. Deer mouse and muskrat appeared to be at little or no risk with NOAEL-based HQs less than 1.

The Site-Wide BERA concluded the following:

- Most aquatic biota, such as invertebrates and fish, are not expected to be adversely affected by direct contact with and ingestion of surface water because of relatively low PCB toxicity to most aquatic biota.
- PCB contamination of surface water and streambed sediment may adversely affect sensitive piscivorous predators, such as mink, through the consumption of fish.
  - Impaired reproduction is the primary adverse effect predicted for the mink.
  - Other piscivorous predators, such as bald eagles, are potentially at risk based on dietary assumptions (e.g., consumption of fish and foraging takes place mostly within on-site aquatic areas).
- Terrestrial and semi-aquatic biota are potentially at risk from floodplain sediment and surface soil, depending on life cycle characteristics (e.g., foraging behavior, diet, mobility) and predicted sensitivity to PCBs.
  - ~~Omnivorous~~Vermivorous birds (represented by the American robin) that consume a large portion of soil invertebrates (e.g., earthworms) in the diet would be at risk if foraging takes place in areas with higher concentrations.
  - Carnivorous terrestrial mammals (represented by the red fox) would be at risk if foraging is concentrated in floodplain riparian areas where higher concentrations in soil have been detected. These estimates assume the diet for carnivorous terrestrial mammals consists of prey that resides in areas with higher concentrations with bioaccumulation of PCBs within the food chain.
  - Carnivorous birds (represented by the great horned owl), depending on dietary assumptions, may be at potential risk. Potential risks calculated for these receptors were associated with elevated PCB concentrations in eggs; risk estimates based solely on food web modeling were comparatively low. Food web risk estimates based solely on terrestrial exposure may underestimate or overestimate risk, introducing some uncertainty in the estimation of risk.
  - Omnivorous terrestrial species (represented by mice) are not expected to be at risk unless the species resides in the areas with higher concentrations. Based on the data collected during the BERA, PCB uptake in mice appeared to be relatively low.
  - Semi-aquatic herbivorous mammals (represented by the muskrat) are potentially at risk from PCB contamination because estimated dietary doses exceed recommended threshold values for laboratory rats. This conclusion was based on the assumption that laboratory rats and muskrats are equally sensitive to PCBs via ingestion. PCB concentrations in muskrats were concluded to present potential adverse effects to muskrat predators because some muskrats contained PCBs in excess of recommended dietary limits for PCB-sensitive predators, such as mink.

Terrestrial receptors (e.g., insectivorous birds, vermivorous mammals, ~~omnivorous~~vermivorous birds, and carnivorous mammals and birds) were reevaluated as part of the Area 1 TBERA and are discussed further in Section 1.3.3.4.

1.3.3.4 Summary of Area 1 TBERA

~~The Area 1 TBERA (ARCADIS 2012d) incorporated the results of the Ecological Risk Studies Peer Review Panel (Dickson et al., 2008) and additional data, and assessed residual risks after completion of the TCRAs for the former Plainwell Impoundment and Plainwell No. 2 Dam Area.~~ An updated Area 1 TBERA for terrestrial birds and mammals is included as Appendix B to the USEPA-approved Area 1 SRI Report (ARCADIS 2012d). The Area 1 TBERA did not revisit the aquatic portion of the Site-Wide Baseline Ecological Risk Assessment (BERA) conducted by CDM on behalf of MDEQ (CDM 2003a), but rather carried forward the BERA conclusions relative to aquatic receptors. The aquatic receptors which are most at risk (i.e., mink) are primarily exposed via the consumption of PCB-containing fish. To address risks to aquatic-feeding receptors, the focus of remedy planning for sediments is the reduction of PCB concentrations in fish.

The development of the Area 1 TBERA was a coordinated effort among Georgia-Pacific, USEPA, the State of Michigan, and the U.S. Fish and Wildlife Service (USFWS). The participants agreed on key inputs and elements of the assessment, including establishing the focus of the Area 1 TBERA on the terrestrial environment, receptors, and pathways within the former Plainwell Impoundment and the Plainwell No. 2 Dam Area. These two areas were the focus of recent TCRAs completed to address PCBs; therefore, the participants agreed to have the update focus on the assessment of residual risks ~~(i.e., risks remaining after completion of removal actions in these two areas) for~~to terrestrial receptors ~~that live and feed within the floodplains of~~associated with PCB exposure via the food chain in the former Plainwell Impoundment and the Plainwell No. 2 Dam Area. ~~The evaluation incorporated historical data, data from the TCRAs, and data from an intensive post-removal sampling effort by MDEQ in October 2008. The primary exposure medium evaluated in~~ Representative receptors were selected as the most highly-exposed species likely to inhabit Area 1. The participants also agreed that the Area 1 TBERA ~~was the post-construction PCB concentrations in exposed sediment within the former Plainwell Dam and the Plainwell No. 2 Dam~~would use the inputs to the CDM Site-Wide BERA (CDM 2003a) as a point of departure.

The representative receptors included insectivorous birds (house wren), vermivorous mammals (short-tailed shrew), ~~omnivorous~~vermivorous birds (American robin and American woodcock), ~~and~~ carnivorous mammals (red fox~~)~~), and carnivorous birds (red-tailed hawk). To evaluate risks for the receptors with individual foraging ranges that are smaller than the two areas of assessment (i.e., the American robin, American woodcock, house wren, and short-tailed shrew), a moving-window approach was used to approximate the receptor-specific exposure units (EUs). The moving-window approach provides a continuous measure of exposure for each predetermined home range size across the entire area instead of non-overlapping, discrete home ranges. EPCs were generated using a moving window for small foraging area receptors by calculating a mean exposure estimate for each home range using a circular moving window of ~~varying~~a given size over a spatially~~-~~interpolated PCB concentration surface. Mean EPCs were calculated based on the interpolated surface for a large number of possible home ranges (e.g., over 2 million in the former Plainwell Impoundment) using unbiased and biased ~~sediment~~floodplain soil data. EPCs for wide ranging receptors (i.e., red fox and red-tailed hawk) were assessed for the two areas separately using unbiased floodplain soil data. Area-wide EPCs were estimated as an area-weighted mean. At the request of USEPA, risk associated with exposure to 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalents (TEQs) was also considered for a subset of the receptors/exposure scenarios.

HQs were calculated using three approaches to model potential PCB exposure to terrestrial wildlife. Approach 1, the Dietary Approach, estimated average daily doses based on ~~exposed sediment~~floodplain soil and tissue ingestion, and was calculated for both total PCBs (birds and mammals) and TEQs (small mammals only). Two egg-based approaches were modeled for birds at the request of USEPA. In Approach 2~~,~~ (Egg-Based Approach), egg-based exposure to both PCBs and TEQs for robins, woodcocks, and house wrens was estimated by modeling egg tissue concentrations from ~~exposed sediment~~floodplain soil concentrations using a bioaccumulation factor (BAF). An alternate Egg-Based Approach via Dietary Ingestion (Approach 3) was also used to estimate egg-based exposure by incorporating a dietary exposure model to estimate egg tissue TEQ concentrations for the American robin~~. Avian receptor evaluations included HQs based on high sensitivity and midrange sensitivity toxicity reference values (TRVs).~~ (i.e., using a floodplain soil to soil invertebrates to egg BAF). Avian receptor evaluations included HQs based on high sensitivity and mid-range sensitivity toxicity reference values (TRVs). Research on the relative sensitivity of avian species to dioxin-like compounds has shown that the primary mechanisms of PCB toxicity in vertebrate species are aryl hydrocarbon receptor (AhR)-mediated effects. Studies indicated that there are three primary AhR genetic structures, which are associated with high, moderate, and low sensitivity to dioxin-like compounds. Genetic sequencing of the AhR identified the domestic chicken as the most sensitive species. High sensitivity TRVs were based on domestic chicken studies, whereas mid-range sensitivity TRVs were based on a variety of wild species. Two species within the insectivorous birds feeding guild, the grey catbird and the European starling, have been reported as sensitive species and were observed in the Kalamazoo floodplain. The house wren represented these species in the Area 1 TBERA. Other lines of evidence for avian receptors included the evaluation of American robin eggs collected within the former Plainwell Impoundment, the house wren productivity study conducted downstream in the former Trowbridge Impoundment, and the American robin productivity study conducted on the Housatonic River (Henning et al. 2003). Other lines of evidence for vermivorous mammalian receptors included the Housatonic River shrew population demographic study (Boonstra and Bowman 2003).

~~For mammalian receptors,~~Potential risk calculated using the ~~HQ~~ dietary approach (Approach 1) is considered relatively more certain than the egg-based approaches (Approaches 2 and 3), due to the following uncertainties:

- The dietary approach uses species-specific exposure parameters available from species-specific field studies. The lack of species-specific inputs for the egg-based approach results in identical exposure estimates for the species evaluated.
- BAFs used in Approach 2 are based on data that are not specifically spatially related (i.e., the BAF is based on an impoundment-wide soil concentration compared to a mean egg tissue concentration for the house wren eggs collected). Use of broad-scale BAFs applied to 2-acre moving window exposure units results in uncertainty in the egg-based approach.
- Differential uptake of specific PCB congeners through the food chain may occur and result in over- or underestimation of exposure and effects.
- BAFs used to estimate prey tissue for the dietary approach are considered more certain than the BAFs used to estimate egg tissue concentrations for Approach 2. Prey tissue BAFs are estimated from soil and tissue data that are more spatially related because prey tissue and soil were either co-located or collected from a discrete grid. The egg

BAF used for Approach 2 is based on an impoundment-wide mean floodplain soil concentration relative to house wren egg tissue concentrations measured in the former Trowbridge Impoundment. Thus, the egg tissue EPCs are considered less certain than prey tissue EPCs in Approach 1.

- Approach 3 is comprised of two modeling steps to estimate egg exposure: prey-tissue BAFs to estimate a PCB concentration in diet and a diet to egg biomagnification factor to derive an egg concentration. This approach assumes that uptake from diet to eggs is constant and identical for the species, which introduces more uncertainty than Approach 1.
- TEQ concentrations are estimated from modeled total PCB estimates for egg tissue. This conversion of total PCB exposure estimates to TEQs adds uncertainty to the TEQ exposure estimates for Approaches 2 and 3.
- Uncertainty associated with the egg-based TEQ TRVs includes the use of egg-injections as the method of dosing. The unnatural process of injection in a laboratory is not a natural bioaccumulation process, and among other limitations, imparts relatively greater uncertainty than dietary-based estimates supported by site-specific data. PCB concentrations achieved by a single injection compared to concentrations resulting from maternal deposition over time are uncertain.

The Area 1 TBERA results are summarized below and a table listing the results of the moving window analysis is provided as Table1-23.

- Vermivorous mammals (represented by the short-tailed shrew) have some potential for risk (maximum LOAEL HQ of 1.2 for the former Plainwell Impoundment) based on a dietary evaluation.

  Plainwell No. 2 Dam Area:

  - 98% of possible vermivorous mammal home ranges (based on a 1-acre moving window) were protected (i.e., HQs less than or equal to 1.0) based on NOAEL total PCB TRVs in the Plainwell No. 2 Dam Area
  - 73% of possible home ranges were protected based on NOAEL TEQ TRVs in the Plainwell No. 2 Dam Area
  - 100% of possible home ranges were protected based on LOAEL total PCB TRVs in the Plainwell No. 2 Dam Area
  - 100% of possible home ranges were protected based on LOAEL TEQ TRVs in the Plainwell No. 2 Dam Area

  Former Plainwell Impoundment:

  - 66% of possible vermivorous mammal home ranges were protected based on NOAEL total PCB TRVs in former Plainwell Impoundment
  - 41% of possible home ranges were protected based on NOAEL TEQ TRVs in the former Plainwell Impoundment
  - 99% of possible home ranges were protected based on LOAEL total PCB TRVs in the former Plainwell Impoundment
  - 100% of possible home ranges were protected based on LOAEL TEQ TRVs in the former Plainwell Impoundment

Evaluation of a second line of evidence was performed for vermivorous mammals. The Housatonic River shrew study (Boonstra and Bowman 2003) indicated that average PCB concentrations in soil, generally higher than those found within Area 1, resulted in no ~~risk to carnivores~~adverse effects on shrew populations. In the Housatonic River BERA, USEPA reported that shrews living on soils with an average PCB concentration of 21.1 mg/kg did not experience significant effects in population demographics (measured as density, survival, rate of reproduction, sex ratio and growth rate). Although there are uncertainties associated with the Housatonic shrew study (i.e., PCB congener composition, single season study, observed high natural variation in shrew demographics, and the connection between soil concentrations and shrew movement), this line of evidence was given high weight. This study was conducted using the same species (which is considered conservatively representative of small mammal exposure) at a riverine PCB site and has been peer reviewed and accepted by USEPA in risk decision making. Use of the NOAEL soil concentration of 21.1 mg/kg from the Housatonic River shrew study as a protective soil concentration results in a NOAEL dose of 0.78 mg/kg-day, which is more than 3 times higher than the NOAEL TRV and higher than the LOAEL TRV used in the Area 1 TBERA. An additional HQ calculation for mice suggested that the shrew risk model selected to represent a range of small mammals likely overestimates risk to other small mammals because the mice HQs were less than 1.0, indicating no unacceptable risk.

In summary, risk to vermivorous mammals is possible, but unlikely based on the low magnitude of shrew HQs (maximum LOAEL HQ of 1.2), low frequency of possible home ranges with LOAEL HQs greater than 1.0, and the results of the Housatonic River shrew study. Based on estimated NOAEL dietary HQs, carnivorous mammals (represented by the red fox~~)~~ with a home range more than ten times as large as either area) have acceptable risks that are well below 1.0 for both the former Plainwell Impoundment and ~~potential~~the Plainwell No. 2 Dam Area.

- Moderate to low ~~magnitude risk to vermivores~~sensitivity insectivorous birds (represented by the ~~short-tailed shrew).~~house wren) are not at risk.
    - 100% of possible home ranges (based on a 2-acre moving window) were protected (i.e., HQs less than or equal to 1.0) based on NOAEL and LOAEL dietary total PCB HQs and egg-based total PCB and TEQ HQs in Plainwell No. 2 Dam Area
    - 100% of possible home ranges (based on a 2-acre moving window) were protected (i.e., HQs less than or equal to 1.0) based on NOAEL and LOAEL dietary total PCB HQs and egg-based total PCB and TEQ HQs in the former Plainwell Impoundment area
- High sensitivity insectivorous birds (also represented by the house wren) have a potential for risk based on the egg-based HQs (Approach 2), but unacceptable risk is not likely based on dietary HQs (Approach 1).

  Plainwell No. 2 Dam Area:

    - 100% of possible home ranges were protected based on NOAEL and LOAEL dietary total PCB HQs in Plainwell No. 2 Dam Area
    - 61% of the possible home ranges were protected based on LOAEL egg-based total PCB TRVs in Plainwell No. 2 Dam Area
    - 22% of the possible home ranges were protected based on LOAEL egg-based TEQ TRVs in Plainwell No. 2 Dam Area

  Former Plainwell Impoundment:

- 99.9% of possible home ranges were protected based on NOAEL dietary total PCB HQs (maximum HQ of 1.1) in the former Plainwell Impoundment area
- 100% of possible home ranges were protected based on LOAEL dietary total PCB HQs in the former Plainwell Impoundment area
- 30% of the possible home ranges are protected based on LOAEL egg-based total PCB TRVs in the former Plainwell Impoundment area
- 16% of the possible home ranges are protected based on LOAEL egg-based TEQ TRVs in the former Plainwell Impoundment area

Evaluation of a second line of evidence ~~considered for the shrew, the Housatonic~~for insectivorous birds included the house wren productivity study conducted by Michigan State University (MSU) in the former Trowbridge Impoundment of the Kalamazoo River ~~shrew~~. This study~~,~~ indicated no ~~unacceptable risk.~~PCB-related impacts on house wrens in an area with PCB concentrations greater than those found in Area 1. Although there are uncertainties with the study design, sample size, and habitat differences between the study area and reference area, egg-tissue regression analyses indicated that egg PCB concentrations were not correlated with adverse impacts on productivity. Based on the results of the house wren study and the HQs for the mid-range sensitivity TRVs, unacceptable risk to moderate or low sensitivity insectivorous birds in Area 1 is not anticipated. For high sensitivity insectivorous species, the dietary LOAEL HQs were less than 1.0 for all possible home ranges, while the LOAEL egg-based HQs were greater than 1.0 for a large percentage of possible home ranges. For Plainwell No. 2 Dam Area, between 39% and 78% of the possible home ranges were not protected based on LOAEL TRVs. For the former Plainwell Impoundment area, between 70% and 84% of the possible home ranges were not protected based on LOAEL TRVs. Based on the evaluation of uncertainty associated with each HQ approach, there is higher confidence in the dietary HQs than the egg-based HQs. Thus, unacceptable risk to high sensitivity insectivorous bird species in Area 1 is not expected, but is possible based on the HQs developed using Approach 2 (egg-based).

- ~~For avian receptors, risks were assessed for high, moderate, and/or low-sensitivity insectivores, vermivores, and carnivores. The HQ results based on the mid-range sensitivity TRVs supported a conclusion of no unacceptable risk to moderate-sensitivity avian species (represented by the American robin and American woodcock) or low-sensitivity avian species (represented by the red-tailed hawk). The multiple lines of evidence considered support conclusions of no unacceptable risk to a moderate- or low-sensitivity species.~~
- ~~No high-sensitivity vermivores have been identified among the large number of species observed at the Site in over 30 years of surveys conducted by the Kalamazoo River Nature Center. Moreover, the Audubon database for Michigan was reviewed, and all birds with a predominantly vermivorous diet that have been observed in the state were evaluated and found to be moderately sensitive. Thus, the category of high-sensitivity vermivores is not applicable to the Site. For high-sensitivity insectivores (e.g., the grey catbird and European starling, represented by the house wren), the results were not in agreement: one approach indicated no unacceptable risk and a second indicated potential risk. Because the sensitivity of all species observed at the Site has not been evaluated, it is possible that other high-sensitivity insectivorous, omnivorous, or herbivorous species are present. These species would not necessarily be at risk, because the risk assessment for high-sensitivity insectivores represents the high end of exposure relative to omnivores and herbivores.~~

~~Overall, the Area 1 TBERA found no unacceptable risk to either carnivorous birds and mammals or low-to-moderately sensitive birds. PCB concentrations remaining in the floodplains of the former Plainwell Impoundment and Plainwell No. 2 Dam Area are below levels that might present risks to carnivorous mammals and low- or moderately sensitive species of birds. Potential risk was identified for vermivorous mammals in localized areas. Potential, but inconclusive, risk was also identified for high-sensitivity insectivorous birds and vermivorous birds (i.e., birds with greater than 40 percent worms in diet), if present.~~

- Highly exposed (i.e., greater than 40% terrestrial invertebrates), moderate to low sensitivity vermivorous birds (represented by the American robin) are not considered at risk
  - 100% of possible home ranges (based on a 2-acre moving window) were protected based on NOAEL and LOAEL dietary total PCB (Approach 1) and egg-based total PCB and TEQ HQs (both NOAEL and LOAEL for Approaches 2 and 3) in Plainwell No. 2 Dam Area
  - 100% of possible home ranges were protected based on NOAEL and LOAEL dietary total PCB (Approach 1) and egg-based total PCB and TEQ HQs (both NOAEL and LOAEL for Approaches 2 and 3) in the former Plainwell Impoundment area
- Unacceptable risk to highly exposed, high sensitivity vermivorous species (represented by the American robin) is possible, but considered unlikely.

  Plainwell No. 2 Dam Area:
  - 100% of possible home ranges (based on a 2-acre moving window) were protected based on NOAEL and LOAEL dietary total PCB (Approach 1) in Plainwell No. 2 Dam Area
  - 61% of the possible home ranges were protected based on LOAEL egg-based total PCB TRVs (Approach 2) in Plainwell No. 2 Dam Area
  - 22% of the possible home ranges were protected based on LOAEL egg-based TEQ TRVs (Approach 2) in Plainwell No. 2 Dam Area
  - 6% of the possible home ranges were protected based on LOAEL egg-based approach via dietary ingestion TEQ TRVs (Approach 3) in Plainwell No. 2 Dam Area

  Former Plainwell Impoundment:
  - 96% of possible home ranges were protected based on NOAEL dietary total PCB HQs (Approach 1; maximum HQ of 1.3) in the former Plainwell Impoundment area
  - 100% of possible home ranges were protected based on LOAEL dietary total PCB (Approach 1) in the former Plainwell Impoundment area
  - 30% of the possible home ranges are protected based on LOAEL egg-based total PCB TRVs (Approach 2) in the former Plainwell Impoundment area
  - 16% of the possible home ranges are protected based on LOAEL egg-based TEQ TRVs (Approach 2) in the former Plainwell Impoundment area
  - 11% of the possible home ranges are protected based on LOAEL egg-based approach via dietary ingestion TEQ TRVs (Approach 3) in the former Plainwell Impoundment area
- Site-specific measured PCB egg concentrations were used as a second line of evidence and indicated that the HQ egg-based model (Approach 2) results in an

over-estimation of potential robin exposure based on current site conditions. The Housatonic River robin study (Henning et al. 2003) was used as a third line of evidence for vermivorous birds and indicated no impacts on robin productivity at floodplain soil PCB concentrations higher than those observed within Area 1 and at measured egg concentrations almost an order of magnitude higher than those predicted for Area 1.

- Highly exposed, moderate to low sensitivity vermivorous birds (represented by the American woodcock) are not considered at risk
  - 100% of possible home ranges (based on an 11-acre moving window) were protected based on NOAEL and LOAEL dietary total PCB (Approach 1) and NOAEL and LOAEL egg-based total PCB and TEQ HQs (Approach 2) in Plainwell No. 2 Dam Area
  - 100% of possible home ranges were protected based on NOAEL and LOAEL dietary total PCB (Approach 1) and LOAEL egg-based total PCB and TEQ HQs (Approach 2) in the former Plainwell Impoundment area
  - 93% of possible home ranges were protected based on NOAEL dietary total PCB HQs (maximum HQ of 1.3) in the former Plainwell Impoundment area
- Unacceptable risk to highly exposed, high sensitivity vermivorous species (represented by the American woodcock) is possible, but considered unlikely.

  Plainwell No. 2 Dam Area:

  - 100% of possible home ranges were protected based on NOAEL and LOAEL dietary total PCB (Approach 1) in Plainwell No. 2 Dam Area
  - 65% of the possible home ranges are protected based on LOAEL egg-based total PCB TRVs (Approach 2) in the Plainwell Dam No. 2 Area
  - 17% of the possible home ranges are protected based on LOAEL egg-based TEQ TRVs (Approach 2) in the Plainwell Dam No. 2 Area

  Former Plainwell Impoundment:

  - 65% of possible home ranges were protected based on NOAEL dietary total PCB (Approach 1; maximum HQ of 2.0) in the former Plainwell Impoundment area
  - 86% of possible home ranges were protected based on LOAEL dietary total PCB (Approach 1) in the former Plainwell Impoundment area
  - 23% of the possible home ranges were protected based on LOAEL egg-based total PCB TRVs (Approach 2) in the former Plainwell Impoundment area
  - 9% of the possible home ranges were protected based on LOAEL egg-based TEQ TRVs (Approach 2) in the former Plainwell Impoundment area

In summary, risk to vermivorous avian species in Area 1 is considered unlikely based on mid-range sensitivity TRVs because LOAEL HQs were less than 1.0. High sensitivity TRVs resulted in HQs greater than 1.0 for both dietary (in former Plainwell Impoundment only) and egg-based exposures; however, no small ranging, highly exposed, high sensitivity vermivores have been observed at the Site in over 30 years of surveys conducted by the Kalamazoo River Nature Center. Given the low probability that highly exposed (i.e., greater than 40% terrestrial invertebrates in diet), high sensitivity avian vermivores are present in Area 1, ecologically significant adverse effects on vermivorous birds in Area 1 is possible, but not likely.

- Carnivorous birds (represented by the red-tailed hawk) are not considered to be at risk.
  - 100% of possible home ranges were protected based on mid-range and high sensitivity NOAEL and LOAEL dietary total PCB TRVs (Approach 1) in Plainwell No. 2 Dam Area
  - 100% of possible home ranges were protected based on mid-range and high sensitivity NOAEL and LOAEL dietary total PCB TRVs (Approach 1) in the former Plainwell Impoundment area

1.4 PRIOR REMEDIAL ACTIONS

Overall, the Area 1 TBERA found no unacceptable risk to either carnivorous birds and mammals or mid-range sensitivity birds. Possible risk was identified for vermivorous mammals in localized areas. Possible, but inconclusive, risk was also identified for high-sensitivity insectivorous birds and vermivorous birds (i.e. birds with greater than 40% terrestrial invertebrates in diet), if present. However, highly exposed, high sensitivity vermivorous birds have not been observed at the Site. Based on the results of the TBERA and the acknowledged uncertainty in the risk estimates, reduction of unacceptable risks to terrestrial ecological receptors is considered in this FS.

In keeping with USEPA's principles for managing sediment sites (USEPA 2002), controlling sources of PCBs has been a goal of cleanup activities completed throughout Area 1 since 1998, when one of the furthest upstream source of PCBs, Bryant Mill Pond, was addressed through a removal action. These efforts have included two TCRAs in the former Plainwell Impoundment and the Plainwell No. 2 Dam Area, work at former paper mill properties, and cleanups at locations next to Area 1 along Portage Creek and the Kalamazoo River that were used as disposal sites for papermaking residuals and wastes. One such cleanup was an Emergency Response Action completed by Weyerhaeuser, under the direction of USEPA, between November 2007 and April 2008 to "prevent, abate, or minimize a release or potential release from the former Plainwell Mill banks" (RMT 2008). The various projects completed to date are summarized in Table 1-~~23~~24.

Table 1-~~23~~24. Summary of Response Actions in Area 1***

Location	Dates of Action	Response Actions
Allied Paper, Inc. Operable Unit	1998–2004	• Excavated 146,000 cubic yards (cy) of materials from Bryant Mill Pond (1998-1999) • Stabilized berms and installed sheet pile walls along Portage Creek (completed in 2001) • Removed 2,000 cy of materials from along Portage Creek and consolidated at the OU (2002) • Installed Part 115 cover system across 18-acre landfill site (completed in 2003)
King Highway Landfill Operable Unit (KHL OU)	1994–2000	• Excavated 58,000 cy of materials: King Street Storm Sewer, Kalamazoo Mill Lagoons, King Mill Lagoons, the river next to the KHL OU and other locations • Installed Part 115 cover system across 23-acre site • Stabilized berms around the OU and installed a sheet pile wall along the Kalamazoo River

Location	Dates of Action	Response Actions
Willow Boulevard/A-Site Landfill Operable Unit	1999–2000	• Stabilized A-Site berms and installed a sheet pile wall along the Kalamazoo River • Excavated 7,000 cy sediment from the river next to Willow Boulevard • Consolidated materials at Willow Boulevard Site, regraded area, and installed a sand/soil cover for erosion protection
Plainwell Mill*	2007–2008	• Removed 4,700 cy of soil from riverbank and disposed off site
Former Plainwell Impoundment TCRA	2007–2009	• Removed 126,700 cy sediment and soil and disposed off site • Reconstruction/erosion control of riverbanks
Kalamazoo Mill/ Hawthorne Mill TCRA**	2007–2009	• Removed 50,000 cy soil from mill properties and disposed in A-Site
Plainwell No. 2 Dam Area TCRA	2009–2010	• Removed 15,700 cy sediment and soil and disposed off site • Reconstruction/erosion control of riverbanks
12th Street Landfill Operable Unit*	2010–2011	• Consolidation of PCB-containing materials • Installed Part 115 landfill cover system
Willow Boulevard/A-Site Landfill Operable Unit	2011–2013	• Consolidation of PCB-containing materials into landfills • Installed Part 115 landfill cover system
Portage Creek TCRA	~~Began in~~ 2012~~. Est. completion late~~ 2013 ~~or early 2014~~	• Removal and off-site disposal of approximately ~~18,140~~23,700 cy of sediment and soil from and along the creek ~~(volume estimate as of early 2013).~~.
Bryant Mill Pond TCRA	1998–1999	• Removal of 150,000 cy of sediment and floodplain soil in Bryant Mill Pond and along Portage Creek • Consolidation of PCB-containing materials under cap in former dewatering lagoons
Allied Paper, Inc. Operable Unit	To be determined	• Remedial alternatives in FS ~~call for~~include consolidation of PCB-containing materials and installation of a cap over the OU

* Weyerhaeuser Co. is the responsible party at the Plainwell Mill and the 12th Street Landfill Operable Unit.
** After the Kalamazoo Mill/Hawthorne Mill TCRA and documentation under the SRI/FS AOC that the two mill properties were no longer sources of PCBs to the Site, USEPA determined that no further investigation under CERCLA was necessary at either location and the mill properties are no longer considered part of the Site (Karl 2009).
*** Source: Table 2-1 Draft Area 1 ASTM (ARCADIS 2012b), updated with permission.

The following report sections provide additional details on prior removal actions. These activities have resulted and will result in the control or elimination of the most significant known sources of PCBs in Area 1 and are supportive of the recovery of PCB levels in fish tissue.

1.4.1.1 Former Plainwell Impoundment TCRA

USEPA determined that the concentrations of PCBs in the sediment, riverbank soil, and floodplain soil of the former Plainwell Impoundment posed an imminent and substantial danger to both human and ecological receptors. As a result, USEPA determined that a TCRA was necessary to address the contamination. The AOC for the TCRA was issued by USEPA in August 2008. Removal Action construction activities were performed May 2007 through June 2009, followed by post-removal monitoring and maintenance completed in March 2013. The work completed during the TCRA and the effectiveness of the removal action are discussed below.

TCRA Objectives

Source Control

- Cut back and stabilize riverbanks
- Excavate targeted sediment to prevent migration
- Remove near-shore areas, behind the old dam, mid-channel areas with PCBs greater than 50 mg/kg
- Dewater/process/dispose excavated materials
- Control sediment re-suspension during construction

Risk Management

- Remove targeted soil with PCBs greater than 50 mg/kg
- Excavate sediment to mitigate effects of dam removal on downstream transport of PCBs

Restoration

- Monitor effects of lowering water levels on sediment movement during and after dam removal
- Establish stable channel, revegetate work zones
- Monitor restored area, cut-back, and erosion control of riverbanks

Sediment and Soil Removal
Sediment and soil removal areas were subdivided to facilitate removal work, and removal generally proceeded from upstream to downstream. The excavation/removal areas are depicted on Figure 1-6. Approximately 126,700 cy of material was removed and disposed at commercial offsite landfills. This material consisted of approximately 20,860 cy of Toxic Substances Control Act of 1976 (TSCA) material and 105,840 cy of non-TSCA material. Approximately 7,625 linear feet of riverbank were addressed during the TCRA (ARCADIS, 2010e).

The design incorporated removal of sediment (near-shore and PCB “hot spots”) with bank stabilization to prevent downstream migration with dam removal. Near-shore sediment was generally excavated 40 feet outward from the pre-construction top-of-bank (the reach of the excavator). Sediment was removed down to the native (pre-impoundment) gravel riverbed. Mid-channel sediment that could not be safely reached by the excavator in the center of the project area (prism) and that had concentrations of less than 50 mg/kg PCBs were left in place and were expected to erode gradually over time. Sediment immediately upstream of the dam and three deposits of mid-channel sediment with PCB concentrations greater than 50 mg/kg were removed to 1 mg/kg PCB or to the pre-impoundment channel bottom.

Two cofferdams were installed during the project to isolate the materials to be excavated within the former Plainwell Impoundment. The water-level control structure (WCS) facilitated the removal of the remnant power house structure and controlled the water level in the former Plainwell Impoundment, improving the efficiency of sediment removal activities in the downstream portion of the project area. Once the WCS was removed in January 2008, the river was returned to its original channel.

Control systems were installed in the river to minimize downstream transport of resuspended materials associated with the removal of sediment and soil. The systems used included turbidity curtains, a combination of turbidity curtain and flow deflector wall, and fully enclosing steel sheet pile walls. The structures used to control resuspended sediment were capable of functioning under a variety of potential river flow and depth scenarios. Upstream and downstream turbidity was measured and monitored throughout the day, and actions to reduce turbidity were taken when the farthest downstream measurement was two times greater than the concurrent upstream measurement.

Excavation was performed from the top-of-bank using an open bucket long-reach excavator equipped with a real-time kinematic global positioning system (RTK GPS). Excavated soil and sediment was loaded into off-road trucks and hauled to the nearest staging area for temporary storage and processing such as dewatering and consolidation and/or reloaded for offsite disposal in licensed commercial landfills.

Soil removal in the former Plainwell Impoundment included the excavation of 30 feet from the river into the bank/floodplain soil where PCB concentrations exceeded 5 mg/kg (or 4 mg/kg adjacent to residential area). The purpose of the bank removal and restoration was to stem the supply of PCBs to the river from the eroding banks and provide clean buffer to mitigate exposures to PCB-contaminated banks, and control future bank erosion. PCB-contaminated floodplain soil identified from pre-removal action data and containing PCB concentrations greater than 50 mg/kg PCBs was also excavated.

Confirmation monitoring was performed to verify that the design specifications were achieved. An RTK GPS-equipped excavator was used to provide preliminary confirmation that excavation was completed in an area. Confirmation sampling was then performed in removal areas. In some cases where additional material removal was necessary to meet the performance standard, confirmation monitoring affected the depth of excavation. The lateral extent of removal was determined using historical data collected before development of the Design Report. The PCB sampling performance standard for floodplain soil was generally 5 mg/kg, but was reduced to 4 mg/kg in one location where removal was performed near a residential area. The PCB sampling performance standard for sediment was 1 mg/kg. Confirmation sampling results were presented in Table 5 of the Construction Completion Report (ARCADIS, 2010e).

Bank Restoration

As removal operations were completed within a removal area, the banks were reconstructed with clean fill dirt or graded to a stable slope and revegetated. A portion of the banks, where modeling predicted higher erosional forces, were armored with river run rock. Coir log and temporary erosion control fabric were installed as necessary to protect exposed bank soil before the bank could be fully revegetated. Topsoil was installed as necessary to support revegetation. Vegetation and riparian habitat were established by seeding and planting with native plant species as described in the Design Report (ARCADIS 2007).

Grubbed areas that were originally vegetated were restored. Where necessary, a 6-inch layer of topsoil was placed to restore pre-excavation grades, followed by placement of grass seed and straw or an erosion control blanket. New native species trees and shrubs were installed in accordance with the appropriate vegetation zone in which the disturbed area was located.

In accordance with the SRI/FS AOC and as described in the Design Report (ARCADIS 2009), annual monitoring of the restored banks was required for three years following approval of the construction completion report which occurred in March 2010. The condition of restored banks and floodplains was evaluated based on visual inspection, a topographic survey, a bank erosion hazard index (BEHI) rating, and vegetation monitoring. The first bank conditions monitoring report was submitted in July 2011 (ARCADIS 2011b). During the monitoring and maintenance period, maintenance was performed to address bank erosion in areas that did not receive rock armor as part of the original design, replace rock in several areas where the river rock sloughed off the bank, replace or add trees and shrubs, and address invasive species of vegetation, as summarized in Table 1-~~24~~25 for the specified removal subarea.

TCRA Effectiveness

Surface water PCB concentrations, turbidity, temperature, and conductivity were monitored during the TCRA Activities at locations approximately 200 feet from the upstream work limit and 200 to 300 feet from the downstream work limit. Actions were taken to install additional equipment or adjust work activities if the downstream turbidity measurement exceeded two times the concurrent upstream measurement. Surface water data (398 ND [0.05 ug/l MDL] out of 402 samples) indicated that the TCRA construction activities did not result in an increase of PCB loading to areas downstream.

Surface water concentrations declined since 2000/2001 so that post TCRA average surface-water concentrations were 1.1 ng/L, which is consistent with average concentrations in upstream Marrow Lake of 1.0 ng/L. This reduction to background concentrations on average is a result of completing the TCRAs, continued decline in upstream contributions, and a reduced loading of PCBs to the river from external sources.

Table 1-~~24~~25. Summary of Maintenance Work Completed from 2008 to 2013 at the Former Plainwell Impoundment Area TCRA

Removal Area	Year	Description
RA-4A	2012	Angular riprap installed to the predicted river elevation after dam removed (prism-out 2-year river flow elevation). Soil was filled behind riprap in a portion of the area to allow the armored bank to be at a 3:1 slope.
RA-6B & 7	2008	Installed river run rock and coir log to the prism-out median river elevation in western 100 feet of RA-6B and eastern 400 feet of RA-7.
RA-6B	2012 & 2013	Installed angular rip rap at toe of bank and river run rock to the prism-out 2-year river elevation in remaining section not repaired in 2008. Installed live willow stakes above the prism-out 2-year river elevation. Planted willow live plants in 2013 to replace live stakes

Removal Area	Year	Description
		that did not survive.
RA-7, 8, & 9B	2009 & 2013	Installed river run rock and coir log to approximately prism-out median flow elevation in most sections, and to the prism-out 3-year river elevation in the western 125 feet of RA-8 and the eastern 150 feet of RA-9B. Placed willow live plants in 2013.
Ra-9B	2010	Re-graded/vegetated bank around 35-foot bank washout area and installed river run rock to the top of bank
RA-11A	2009	Removed gray material from edge of water and re-graded/reseeded bank in vicinity of the pipeline crossing.
RA-11A, 12A, & 13A	2011	Taller trees were replanted in the vicinity of the great ragweed.
South Bank of Western Channel	2012 & 2013	Installed angular rip rap and river rock on areas of exposed geotextile fabric.
Miscellaneous Areas	2009 & 2010	Herbicide treatment for reed and canary grass
	2011	Herbicide treatment for Phragmites and Purple loosestrife.
	2012	Installed angular rip rap over areas of exposed geotextile

~~**TCRA Effectiveness**~~

~~Surface water PCB concentrations, turbidity, temperature, and conductivity were monitored during the TCRA Activities at locations approximately 200 feet from the upstream work limit and 200 to 300 feet from the downstream work limit. Actions were taken to install additional equipment or adjust work activities if the downstream turbidity measurement exceeded two times the concurrent upstream measurement. Surface water data (398 ND [0.05 ug/l MDL] out of 402 samples) indicated that the TCRA construction activities did not result in an increase of PCB loading to areas downstream.~~

~~Surface water concentrations declined since 2000/2001 so that post TCRA average surface-water concentrations were 1.1 ng/L, which is consistent with average concentrations in upstream Marrow Lake of 1.0 ng/L. This reduction to background concentrations on average is a result of completing the TCRAs, continued decline in upstream contributions, and a reduced loading of PCBs to the river from external sources~~Yearling smallmouth bass were sampled in the Otsego City impoundment immediately downstream of the TCRA area, to assess potential impacts associated with release/erosion of sediment during the Plainwell Impoundment TCRA. Three sampling events were carried out, with the first in 2006 occurring before the TCRA. The other two sampling events were performed in 2007, after the first year of the TCRA and in 2008, after the second year of the TCRA. There was not a statistically significant difference in the average lipid-adjusted PCB concentration before and after the TCRA. Fish tissue trends are discussed in Section 1.3.1.3 above.

Adult fish tissue concentrations declined from 2006 to 2011 at a rate of 1.9 to 7.7% for the first order decay regression model and 2 to 10.4% for the mixed-order regression model where the trend converged or the trend was statistically significant. This decrease in fish tissue PCB concentrations is a result of several factors, as listed above for surface water, including completion of the TCRAs in Area 1.

Soil and sediment confirmation sampling was performed during the TCRA activities as discussed above. Soil and sediment were excavated an additional 6 inches where confirmation samples indicated PCB concentrations remained above the performance standard. If the second round of confirmation sampling indicated PCB concentrations above the performance standard, additional excavation or placement of clean backfill material was performed as decided in the field through discussions with USEPA.

Post-removal surface sediment sampling was performed in January 2008 for areas excavated during 2007, and in March 2009 for the areas excavated in 2008. Seventy-five locations were sampled. The PCB concentrations ranged from ND to 48 mg/kg, with an average PCB concentration of 1.7 mg/kg.

The pre-TCRA soil PCB SWAC (top 6 inches) in the former Plainwell Impoundment was 17 mg/kg. Data representative of post-TCRA soil PCB levels indicated that the floodplain soil SWAC is 6.6 mg/kg (see Section 6.3.4 of the Area 1 SRI Report [ARCADIS 2012a]).

Post-removal sampling of the Mid-Channel (prism) sediment found average PCB concentrations of less than 0.6 mg/kg. Bathymetric monitoring of the prism sediment was performed twice per year to assess prism erosion. The 80 percent decrease in the prism (AOC goal) was reached in May 2010, 17 months after the WCS was removed.

Groundwater sampling was performed for 5 quarters in a network of 15 monitoring wells. PCBs were not detected in groundwater. Groundwater is not a medium of concern.

1.4.1.2 Plainwell No. 2 Dam Area TCRA

USEPA determined that a TCRA was necessary to address areas that represent potential sources of PCBs to the river after reviewing the results of sampling and investigation work in the Plainwell No. 2 Dam Area completed pursuant to the SRI/FS AOC. Areas targeted for this TCRA included bank soil, sediment in a portion of a historical oxbow channel, and soil in a floodplain area next to the oxbow (Figure 1-7).

The following activities were performed as part of this TCRA:

- Stem the potential loading of PCBs to the Kalamazoo River from riverbanks in the Plainwell No. 2 Dam Area
- Remove sediment at the mouth of and along the western side of the former oxbow channel
- Dispose of the removed PCB-containing bank soil and sediment in a way that did not present unreasonable risk to human health or the environment
- Mitigate potential adverse environmental impacts of construction
- Complete habitat enhancement

Soil and Sediment Removal

Sediment and soil removal areas were subdivided to facilitate removal work, and removal generally proceeded from upstream to downstream. The removal areas designated are depicted on Figure 1-6 (ARCADIS 2011). Removal activities on the north side of the river were performed in 2009 and removal activities on the south side of the river were performed in 2010. Approximately 15,700 cy of material were removed and disposed in off-site licensed commercial landfills as a result of TCRA activities. Approximately 10,000 linear feet of riverbank were addressed by the TCRA.

Control systems were installed in the river to minimize downstream transport of resuspended materials associated with the removal of sediment and soil. The system used throughout the TCRA included turbidity curtains combined with a flow deflector wall. The selected systems had a relatively short setup/breakdown time and could be easily modified to adapt to changes in field conditions.

Excavation was performed from the top-of-bank using an open bucket excavator equipped with a RTK GPS. Excavated soil and sediment were loaded into off-road trucks and hauled to the nearest staging area for temporary storage and processing, and/or reloaded for offsite disposal in licensed commercial landfills.

Confirmation monitoring was performed to verify that the design specifications were achieved. An RTK GPS-equipped excavator was used to give preliminary confirmation that excavation was completed in an area. Confirmation sampling was then performed in the removal areas to verify that no unacceptable PCB concentrations remained within the excavation boundaries. In some cases where additional material removal was necessary to meet the performance standard, confirmation monitoring affected the depth of excavation. The lateral extent of removal was determined using historical data collected before development of the Design Report.

Soil removal included the excavation of 30 feet from the river into the bank/floodplain soil where PCB concentrations exceeded 5 mg/kg (or 4 mg/kg adjacent to residential area). The purpose of the bank removal and restoration was to stem the supply of PCBs to the river from the eroding banks and provide clean buffer to mitigate exposures to PCB-contaminated banks, and control future bank erosion. PCB-contaminated floodplain soil identified from pre-removal action data and containing PCB concentrations greater than 50 mg/kg PCBs was also excavated.

Bank Restoration

As removal operations were completed within a removal area, the banks were reconstructed or graded to a stable slope and revegetated in a manner similar to that described above for the Plainwell Dam Removal TCRA.

In accordance with the SRI/FS AOC and as described in the Design Report (ARCADIS, 2009), annual monitoring of the restored banks is required for three years following approval of the construction completion report which occurred in March 2011. The condition of restored banks was evaluated based on visual inspection, topographic survey, a BEHI rating, and vegetation monitoring. The first bank conditions monitoring report was submitted in July 2011 (ARCADIS, 2011b). This report found that 96% of the restored banks received a BEHI rating of Low and 4% received a BEHI rating of Moderate, indicating that most of the bank restoration measures were controlling erosion. It was expected that the portions rated with a Moderate potential for erosion would improve to Low as vegetation density and root depth increased. Subsequent bank surveys characterized the restored areas with a rating of Low. Tree and shrub survival in the restored areas did not meet the 85% performance standard, and replacement plantings were installed in 2012. In January 2013 bank maintenance was completed in one removal area that was observed during the 2012 monitoring to exhibit significant bank erosion. The area was armored. In November 2013 and January 2014 bank maintenance was performed in parts of three removal areas that were observed during the 2013 monitoring to exhibit significant bank erosion. Brush wattles and woody debris were installed in the river along the bank for about 800 feet in the three areas. Woody live plants are planned to be planted in the same areas in the Spring of 2014. All four additional areas are currently being evaluated due to the bank erosion observed during the 2013 monitoring. All five of these areas did not include rock armoring as part of the original design. A summary of maintenance activities is provided in Table 1-~~25.~~26.

~~**Table 1-25**~~

~~**Summary of Maintenance Work Completed at the Plainwell No. 2 Dam Area TCRA (2011–2013)**~~

~~Removal Area~~	~~Year~~	~~Description~~
~~RA-3A~~	~~2012~~	~~Installed river run rock and coir log to the median river elevation for 150 feet.~~

TCRA Effectiveness
Surface water PCB concentrations, turbidity, temperature, and conductivity were monitored during the TCRA Activities at locations approximately 200 feet from the upstream work limit and 200 to 300 feet from the downstream work limit. Surface water data indicated that the TCRA activities did not result in an increase of solids or PCB loading to areas downstream.

Surface water concentrations declined since 2000/2001 so that post TCRA average surface-water concentrations were 1.1 ng/L, which is consistent with average concentrations in

Table 1-26
Summary of Maintenance Work Completed at the Plainwell No. 2 Dam Area TCRA (2011–2014)

Removal Area	Year	Description
RA-3A	2012	Installed river run rock and coir log to the median river elevation for 150 feet.
RA-2, 3A. & 4A	2013 and 2014	Installed brush wattles and woody debris (2013 and 2014); plant woody vegetation along 800 feet of bank (2014)
Miscellaneous Areas	2011 and 2012	Herbicide application to control purple loosestrife.
	2012	Trees replanted due to low survival rate as the result of high river levels and beaver harvesting.
	2013	Purple loosestrife control with Galerucella beetles.

upstream Marrow Lake of 1.0 ng/L. This reduction to background concentrations on average is a result of completing the TCRAs, continued decline in upstream contributions, and a reduced loading of PBCBs to the river from external sources.

Adult fish tissue concentrations declined from 2006 to 2011 at a rate of 1.9 to 7.7% for the first order decay regression model and 2 to 10.4% for the mixed-order regression model where the trend converged or the trend was statistically significant. This decrease in fish tissue PCB concentrations is a result of several factors, as listed above for surface water, including completion of the TCRAs in Area 1.

Soil and sediment confirmation sampling was performed during the TCRA activities as discussed above. The PCB sampling performance standard was 5 mg/kg for soil throughout the project area, and 1 mg/kg for sediment in the oxbow area. Soil confirmation sampling was carried out before placement of backfill that was placed in most soil removal areas. The only exception was along certain portions of the riverbanks where the post-excavation elevation did not require backfill.

The pre-TCRA soil PCB SWAC in the Plainwell No. 2 Dam Area was 3.2 mg/kg. The current post-removal SWAC is 2.4 mg/kg. The pre and post-removal SWAC for sediment in the oxbow was 18 mg/kg and 6.6 mg/kg, respectively. This post-removal SWAC is below the recommended soil PRG of 11 mg/kg PCBs. PRGs are presented in Section 2.4.7 (see Section 6.3.4 of the Area 1 SRI Report [ARCADIS 2012a]).

1.4.1.3 Bryant Mill Pond TCRA

An important effort in reducing PCB concentrations in Portage Creek was the Bryant Mill Pond TCRA performed by USEPA. Bryant Mill Pond is a 71-acre site on Portage Creek and was the furthest upstream source of PCBs to OU-5 (MDEQ 1999). A TCRA was performed in 1998 and 1999 to remove 150,000 cy of sediment and floodplain soil. PCB concentrations in the area were found to be as high as 1,000 mg/kg prior to the Removal Action. Excavated materials were placed in former dewatering lagoons and capped. The lagoons are on higher ground and are protected from stream flows by a stabilized dike.

TCRA Effectiveness

Post-removal PCB concentrations in sediment following the Bryant Mill Pond TCRA were below 0.46 mg/kg, and 92 percent of post-remediation samples in the area overall were below the PCB remedial goal of 1 mg/kg (MDEQ 1999). PCB concentrations in Portage Creek surface water in the former Bryant Mill Pond area were reduced by two orders of magnitude following the TCRA, and PCB concentrations in fish tissue were reduced by one order of magnitude and have been maintained in carp and whole body white suckers since 1998/1999 (Kern 2013).

1.4.1.4 Portage Creek TCRA

USEPA determined that the concentrations of PCBs in the sediment and riverbank soil in Portage Creek between East Cork Street and the confluence with the Kalamazoo River posed an imminent and substantial danger to both human and ecological receptors. As a result, USEPA ~~is currently leading~~completed a TCRA to address this contamination.

The following activities ~~are being~~were performed as part of this TCRA:

- Installation of a cofferdam and creek diversion system
- Removal of PCB-contaminated sediment with a post-removal cleanup goal of 1 mg/kg
- Removal of riverbank and floodplain soil with a post-removal cleanup goal of 5 mg/kg
- Dewatering, as necessary, and disposal of removed PCB-contaminated sediment and soil in offsite commercial landfills
- Control of resuspended sediment
- Establishment of erosion control for the river channel post-removal and revegetation with native plant species
- Monitoring during and after the removal action

Soil and Sediment Removal

Sediment and soil removal areas were subdivided to facilitate removal work. Removal is generally proceeding from upstream to downstream. Removal Action activities began in April 2012 and ~~are expected to be~~were completed ~~during the~~in November 2013~~ construction season or the beginning~~. A total of ~~the 2014 construction season, depending on river conditions. The initial estimate for ~~23,700 cy of soil and sediment ~~removal ~~was ~~approximately 17,000 cy~~removed from approximately 1.8 linear miles of creek bank (~~Environmental Quality Management, 2011); however, that estimate has increased to 18,140 cy (~~November 2013, USEPA~~, 2013a). Planned~~ Public Meeting Flyer). Removal depths are approximately 1 foot to 4.6 feet. The estimated pre-removal SWAC for Portage Creek sediment and soil ~~is~~was 6.1 mg/kg (USEPA 2012).

Sediment ~~is~~was removed from the creek by mechanical dredging techniques, including the use of long-reach excavators equipped with both environmental buckets and standard excavating buckets and RTK GPS. Excavation ~~is~~was performed to the initial target depth; if visible contamination is still apparent in the grid(s), samples ~~are~~were collected in every other grid of the slope area to verify remaining contamination. If warranted in a particular grid(s), overexcavation ~~is~~was performed until visible evidence of paper sludge or contaminated sediment ~~has been~~was removed. Samples ~~are~~were then collected in each grid. If cleanup performance goals ~~are~~were met in each grid, backfilling ~~proceeds~~proceeded. If a grid ~~fails~~failed to meet performance goals, the excavation and sampling process ~~is~~was repeated as needed (or as directed by the USEPA OSC) prior to backfilling (Environmental Quality Management, 2013).

Excavation areas in the creek ~~are~~were isolated by the use of various methods, including installation of steel sheet pile cofferdams and pumping the water around the excavation areas and discharging it back into the creek downstream of the active excavation sites. Silt curtains ~~are~~were placed in strategic locations in Portage Creek to control turbidity during sediment excavation. Solidification of creek sediment ~~takes~~took place either in the streambed or in a miser box immediately adjacent to the streambed. The material ~~is~~was hauled by dump trucks to the staging area for dewatering and further processing (Environmental Quality Management, 2011).

Removed soil and sediment ~~are~~were dewatered and then separated for disposal at TSCA- or non-TSCA-licensed landfills offsite. Recharge groundwater in the excavation, decontamination water, and liquids removed during dewatering ~~are~~were treated at an on-site wastewater treatment plant and discharged back to Portage Creek (USEPA, 2013b).

~~During the 2012 construction season, 12,000 cy of soil and sediment was removed from Portage Creek between Reed and Vine streets. USEPA returned in 2013 to remove additional sediment and soil from the creek between Dutton Street and Michigan Avenue. Confirmation monitoring will be performed to verify that the post-removal goals were achieved.~~

Bank Restoration

The restoration plan for the Portage Creek TCRA was published in the R*estoration Plan for Portage Creek Area Time Critical Removal Action Kalamazoo County, Kalamazoo, Michigan*, report prepared by Environmental Quality Management (2011).

Removal areas ~~are~~were backfilled with clean sediment and restored with native trees and vegetation. Restoration activities ~~include~~included returning disturbed areas to pre-construction conditions. This ~~involves~~involved aggregate placement in the creek; removal of temporary roads and project support structures/facilities; and grading, seeding, and replanting native perennials removed during construction work. Other restoration or environmental enhancement work activities ~~include~~included, as necessary, installation of coir logs at the toe of the slope and armoring the toe slope portions of the creek with rock. Restoration activities ~~will be~~were monitored for one year following completion, including monitoring progress of restorative planting and maintenance of site erosion and sedimentation controls (Environmental Quality Management 2011).

TCRA Effectiveness

Post-removal monitoring to verify the effectiveness of the Portage Creek TCRA ~~currently being implemented~~ will include surface water monitoring, soil and sediment confirmation monitoring, fish tissue monitoring, and monitoring/maintenance of erosion controls.~~ Completion of the ongoing work is anticipated by the end of 2013 or in early 2014. USEPA's estimate of the anticipated~~ USEPA's estimated post-removal PCB SWAC in Portage Creek sediment and soil is 1.8 mg/kg (USEPA 2012).

1.5 MEDIA OF CONCERN

The media of concern are sediments, fish, and floodplain soils. Hot spot areas in Sections 2 and 4, the Crown Vantage side channel, and sediment in Section ~~3~~3 are remediation target areas and will be further ~~evaluated as media of concern~~discussed in Sections 2.0 through 4.0 of this FS Report. Remedial alternatives for sediment will address the potential for bank soil erosion and transport. Remedial alternatives for sediment will also include additional post-TCRA sampling in Section 8 as part of remedial design activities. The SWAC for Section 8 is primarily based on pre-TCRA data, and remedial design sampling will be performed to provide current and representative sediment PCB concentrations.

Floodplain soil in the former Plainwell Impoundment study area will be further evaluated as media of concern in Sections 2.0, 3.0, and 5.0 of this FS Report. In addition, an evaluation of potential residential exposure to floodplain soil PCB concentrations in the remainder of Area 1 is evaluated, and recommendations for residential property sampling during the remedial design phase are provided in Section 3.0.

2.0 REMEDIAL ACTION OBJECTIVES/GENERAL RESPONSE ACTIONS

2.1 COCs

As described in the Generalized CSM (ARCADIS 2009), the Site data, which have been presented in various documents listed in Section 1.2.4, indicate that PCBs are the primary COCs. The available data indicate that exposure to PCBs will drive risks at the Site, and that management of risks due to PCB exposure will also address risks associated with other constituents. CDM's Site-Wide Baseline Ecological Risk Assessment (BERA) (CDM 2003a) states:

> "*PCB contamination is considered to be the primary focus of this ERA because of the current magnitude and distribution of PCBs throughout the [Site]. This ERA, therefore, does not consider the additional incremental effects that may be caused by other chemical stressors…*"

The Area 1 data suggest that several non-PCB constituents with an affinity for fine-grained organic particles similar to that of PCBs are collocated with PCBs as a result of similar transport and deposition mechanisms. The remedial alternatives evaluation presented in Sections 4.0 and 5.0 will address how a given remedial alternative will affect non-PCB constituents in Area 1.

2.2 RAOs

The development of RAOs and PRGs is the first step in identifying and screening remedial alternatives for addressing the COCs and media of concern (USEPA 1988a). The RAOs presented herein form the basis for the development of the remedial alternatives presented in Sections 4.0 and 5.0.

In accordance with USEPA's *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (USEPA 1988a), RAOs represent contaminant- and medium-specific goals for the protection of human health and the environment. Area 1-specific RAOs were prepared in consultation with USEPA based on available information and standards, such as the preliminary applicable or relevant and appropriate requirements (ARARs), to be considered (TBC) guidelines, and risk-based screening concentrations (RBCs) developed in the human health and ecological risk assessments. RAOs are identified to protect those receptors associated with the exposure pathways and media where risk outside the range acceptable to USEPA may be present. The following four RAOs have been developed for PCB-containing media in Area 1:

- **RAO 1: Protect people who consume Area 1 Kalamazoo River fish from exposure to PCBs that exceed protective levels.** ~~This RAO is expected to be achieved over time to protect the population of people represented by a high-end sports angler, who consumes 100 percent of his/her diet from smallmouth bass from the Kalamazoo River. The goal of this RAO is to reduce PCB concentrations in smallmouth bass fillet within 30 years to the Michigan fish advisory level (assuming two meals per month), to a noncancer HI of 1.0, to a cancer risk of 1 x 10^{-5}, or to background.~~This RAO is expected to be progressively achieved over time by meeting the following targets for fish tissue and sediment:
    - Reduction in fish tissue to the Michigan fish advisory level for smallmouth bass to two meals per month (0.11 mg/kg total PCB concentration) within 30 years;
    - Achievement of a non-cancer HI of 1 and a 10^{-5} cancer risk within 30 years for the high-end sport angler (100 percent bass diet);

- The fish tissue goal for bass will be achieved by reducing the sediment PCB SWAC in each of eight sections of the river in Area 1 to 0.33 ppm or less following completion of the remedial action.

- **RAO 2: Protect aquatic ecological receptors from exposure to concentrations of PCBs in sediment that exceed protective levels for local populations.** This RAO is designed to protect fish-eating birds and mammals by reducing fish tissue PCB concentrations to levels that do not harm the sustainability of local populations of these receptors.
- **RAO 3: Protect terrestrial ecological receptors from exposure to concentrations of PCBs in soil that exceed protective levels.** This RAO is intended to protect local populations of birds and mammals by reducing PCB concentrations in soil to levels that do not harm the sustainability of local populations.
- **RAO 4: Reduce transport of PCBs from Area 1 to downstream Areas of the Kalamazoo River and Lake Michigan.** This RAO includes reducing the potential for erosion and downstream migration of PCB-impacted sediment and riverbank soil.

Floodplain soil data available to date do not indicate an unacceptable risk to residents or recreationists based on average concentrations, therefore an RAO was not developed for this case. Additional data will be collected in residential areas during the remedial design phase to confirm that floodplain soils do not represent unacceptable residential or recreational risk.

The PRGs associated with these RAOs are presented in Section 2.4. The fish tissue goal will be achieved by reducing sediment SWACs for total PCBs in Area 1.

2.3 AREA 1 ARARs

CERCLA specifies that Superfund remedial actions comply with ARARs of relevant federal, state, and local environmental laws (including Section 121 (d)(2)(A), the NCP, and 40 CFR, Part 300, in addition to CERCLA). There are three broad categories of ARARs: chemical-specific, location-specific, and action-specific.

- Chemical-specific ARARs are numerical standards that specify the acceptable amount or concentration of a chemical that may be found in, or discharged to the environment. These ARARs are specific to the type(s) of constituents, pollutants, or hazardous substances at a site, and include state and federal regulations pertaining to contaminant levels in various media.
- Location-specific ARARs are restrictions placed on the concentrations of hazardous substances or the conduct of activities solely based on their specific geographic locations, such as floodplains, wetlands, historic places, or sensitive ecosystems or habitats.
- Action-specific ARARs are technology-based or activity-based requirements or limitations on actions taken regarding hazardous wastes. Action-specific ARARs are regulatory requirements that define acceptable remedial technologies and are triggered by the particular remedial activities that are selected to accomplish a remedy.

An alternative that does not comply with an ARAR but provides protection of human health and the environment may be eligible to have the ARAR waived by USEPA, as described in CERCLA Section 121(d)(4). An ARAR waiver may be obtained under the following circumstances:

- The selected remedial action is only part of a total remedial action that will attain such ARAR when completed.
- Compliance with such ARAR will result in greater risk to human health and the environment than alternative options.
- Compliance with such ARAR is technically impracticable from an engineering perspective.
- The selected remedial action will attain a standard of performance that is equivalent to that required under the given ARAR, through use of another method or approach.
- The requirement is a State requirement that has been inconsistently applied in similar circumstances at other remedial actions within the State.

If an ARAR waiver is appropriate, the reasons for invoking the waiver will be presented in the discussion of the particular remedial alternative.

In accordance with CERCLA Section 121(e), permits are not required for “on-site” CERCLA response actions. However, the selected remedy must comply with the substantive requirements of regulations that otherwise would require permits.

In addition to ARARs, the lead and support regulatory agencies may, as appropriate, identify other advisories, criteria, or guidance to be considered for a particular site. This TBC category consists of non-promulgated advisories, criteria, or guidance developed by USEPA, other federal agencies, states, or localities that may be useful in developing CERCLA remedies. TBCs are not legally binding and lack the status of ARARs. In this Area 1 FS, the remedial alternatives will be screened against their ability to meet ARARs and TBCs.

Identification of ARARs and TBCs was performed on a Site-wide basis and was documented in the Multi-Area Feasibility Study Technical Memorandum Preliminary List of Possible Applicable or Relevant and Appropriate Requirements (ARCADIS 2010a) approved by USEPA on December 23, 2008. This section presents the ARARs and TBCs that are applicable to Area 1. As indicated in the USEPA-approved Area 1 SRI Report (ARCADIS 2012a), groundwater is not a medium of concern within Area 1; therefore, the development of ARARs and TBCs related to groundwater is not necessary.

2.3.1 Chemical-Specific ARARs and TBCs

Chemical-specific ARARs and TBCs that are applicable to surface water, soil, sediment, and other media (e.g., fish) in Area 1 are presented in Table 2-1 and are summarized below. ARARs and TBCs for air are tied to emissions during remedial construction work, and these are presented in the action-specific discussion in Section 2.1.3.

2.3.1.1 Soil-Specific ARARs and TBCs

The provisions of the TSCA, as regulated by 40 CFR Part 761, establish requirements for handling, storage, and disposal of PCB-containing materials. This ARAR may be applicable to PCB-containing materials that either remain in place or are removed from Area 1 during remedial action. For PCB-containing media remaining in place, the selected remedy would be based on meeting site-specific risk goals to attain a standard of performance that is equivalent to that required under TSCA. Because the selected remedy would provide for the protection of human health and the environment through risk management, ~~this ARAR may be waived by USEPA~~a site-specific TSCA equivalency assessment will be required for media left in place. Handling, storage, and disposal of excavated PCB remediation waste material with concentrations greater than 50 mg/kg would require consideration of appropriate disposal technologies.

At the State level, soil are subject to regulations listed in Part 201 of the Natural Resources and Environmental Protection Act of 1994 (NREPA). Generic soil cleanup criteria and screening levels are listed under Attachment 1, Table 2, Soil: Residential and Attachment 1, Table 3, Soil: Nonresidential of the MDEQ's Remediation and Redevelopment Division Operational Memorandum No. 1 (Part 201 Cleanup Criteria/Part 213 Risk-Based Screening Levels). The Part 201 Residential Soil Direct Contact Cleanup Criterion for PCBs is 4 mg/kg and the Nonresidential Soil Direct Contact Cleanup Criterion for PCBs is 16 mg/kg.

The USEPA's Office of Emergency and Remedial Response document, *Guidance on Remedial Actions for Superfund Sites with PCB Contamination* (USEPA 1990), is a TBC and serves as a guideline for handling soil/sediment during remedial action work in Area 1. The USEPA's Office of Research and Development document, *Technology Alternatives for the Remediation of PCB-Contaminated Soil and Sediment* (USEPA 1993), is another TBC and serves as guidance on alternative technologies for the remediation of PCB-contaminated soil and sediment.

2.3.1.2 Sediment-Specific ARARs and TBCs

Sediment are subject to the Clean Water Act of 1972 Section 404 (CWA 404), as regulated by 40 CFR Part 129 and 62 Fed. Reg. 68354 and NREPA, Part 201 (Environmental Remediation). They also address concentrations of COCs in sediment that can adversely affect biota and their habitats. While Part 201 does not include generic sediment cleanup criteria, Area 1-specific cleanup criteria may be required to address exposure scenarios in Area 1. Part 201 allows development of a site-specific cleanup level.

The provisions of the TSCA, as regulated by 40 CFR Part 761, establish requirements for handling, storage, and disposal of PCB-containing materials. This ARAR may be applicable to PCB-containing sediment that either remains in place or is removed from Area 1 during remedial action. For PCB-containing sediment remaining in place, the selected remedy would be based on meeting site-specific risk goals to attain a standard of performance that is equivalent to that required under TSCA. Because the selected remedy would provide for the protection of human health and the environment through risk management, ~~this ARAR may be waived by USEPA~~a site-specific TSCA equivalency assessment will be required for sediment left in place. Handling, storage, and disposal of excavated PCB remediation waste material with concentrations greater than 50 mg/kg would require consideration of appropriate disposal technologies.

2.3.1.3 Water-Specific ARARs

The CWA and TSCA (as regulated under 40 CFR 761.50 (a)) establish effluent standards for contaminants such as PCBs in navigable waters of the United States, and regulate quality standards for surface waters. The ambient water quality criterion for navigable waters is 0.001 microgram per liter (µg/L) total PCBs. The provisions of TSCA [under 40 CFR 761.50 (a)] limit discharges with PCB concentrations exceeding 3 µg/L or outside the allowable discharge limit set in a permit to navigable waters. These ARARs would be applicable to remedial alternatives that include discharge of water to the river.

At the state level, chemical-specific ARARs may include the provisions contained within Part 4 of Part 31 (Water Resources Protection) of NREPA (also called Act 451); Part 4 of Part 31 provides the water quality requirements for surface waters in the state. Prior Substantive Requirement Documents (SRDs) within Area 1 (including the former Plainwell Impoundment

TCRA SRD MIU990025 [MDEQ 2007] and the Plainwell No. 2 Dam Area TCRA SRD MIU990029 [MDEQ 2009]) have specified PCB discharge limitations of 2.6 × 10-5 μg/L. In addition, MDEQ Water Resources Protection has established a water quality value of 0.00012 μg/L for protection of wildlife.

The final Water Quality Guidance for the Great Lakes System (40 CFR Parts 9, 122, 123, 131, and 132) is a chemical-specific TBC. This guidance establishes water quality criteria for 29 pollutants and includes:

- Detailed methodologies for developing criteria for additional pollutants
- Procedures for developing enforceable water-quality-based effluent limits in discharge permits and a total maximum daily load of pollutants that can be allowed to reach the Great Lakes and their tributaries from all sources
- Policies and procedures related to anti-degradation

PCBs are listed in the guidance, with a human health criterion of 3.9×10^{-6} μg/L for both drinking and non-drinking water, and a wildlife protection criterion of 7.5×10^{-5} μg/L.

At the state level, water-specific ARARs may include the provisions contained within Part 4 of Part 31 (Water Resources Protection) of NREPA; this section provides the water quality requirements for surface waters in Michigan and establishes permit requirements for alterations of floodplains and discharges to surface waters.

2.3.1.4 Other Chemical-Specific TBCs

The “trigger levels” used by the MDCH in establishing sport fish consumption advisories and fish consumption guidelines developed by the Great Lakes Sport Fish Advisory Task Force are chemical-specific TBCs. Trigger level concentrations of total PCBs in fish for five consumption frequency categories are set by MDCH and are listed in Table 2-1.

2.3.2 Location-Specific ARARs and TBCs

Location-specific ARARs include requirements that govern activities conducted in floodplains, wetlands, historical areas, and recreational rivers, and activities affecting endangered species. Location-specific ARARs and TBCs that may be applicable to Area 1 are presented in Table 2-2 and are summarized below.

2.3.2.1 Water-Specific ARARs

The CWA (as regulated by 40 CFR Part 132 Appendix E) is applicable to action or activity by any source, point or non-point, of a pollutant that is anticipated to result in an increased loading of bioaccumulative COCs to surface waters of the Great Lakes. MDEQ Administrative Code (R323.1041 through R323.1117) establishes water quality standards for surface water in the State for protection of wildlife and human health.

2.3.2.2 Wetland and Floodplain-Specific ARARs

Federal location-specific ARARs are contained in the Statement of Procedures on Floodplain Management and Wetlands Protection (40 CFR Part 6 Appendix A) Executive Orders 11988 and 11990, which require federal agencies to avoid or minimize adverse impacts of federal actions on wetlands/floodplains. The provisions of CWA 404 would also require a permit for discharge of dredged material into navigable waters, including adjacent wetlands.

State of Michigan location-specific ARARs are contained in several parts of NREPA, including: Part 17 (Michigan Environmental Protection Act), Part 91 (Soil Erosion and Sediment Control), Part 201 (Environmental Remediation), Part 301 (Inland Lakes and Streams), Part 303 (Wetlands Protection), and Part 323 (Shorelands Protection and Management).

2.3.2.3 Endangered Species-Specific ARARs

The Endangered Species Act of 1973 lists species of wildlife and plants identified as endangered or threatened with extinction. Government agencies are required to verify that any action authorized, funded, or carried out does not jeopardize the continued existence of any endangered species or threatened species, or result in the destruction or adverse modification of a critical habitat of such species.

State of Michigan location-specific ARARs related to endangered species are contained in NREPA Part 365 (Michigan Endangered Species Act).

2.3.2.4 Other Location-Specific ARARs and TBCs

Additional location-specific provisions include preservation of historic places and farmland protection. The National Historic Preservation Act of 1966 (regulated by 36 CFR Part 65 and 800) applies to properties/landmarks that are currently listed on the National Register of Historic Places. This is relevant if activities will affect historic properties or landmarks in or near areas of remediation in Area 1.

The Archeological and Historical Preservation Act of 1974 (regulated by 40 CFR Part 6.301[c]) establishes procedures for the preservation of historical and archaeological data that might be destroyed through alteration of terrain as a result of a construction project pertaining to a federally licensed activity or program.

The Farmland Protection Policy Act of 1981 is intended to minimize the impact federal programs have on the unnecessary and irreversible conversion of farmland to nonagricultural uses.

The Fish and Wildlife Coordination Act of 1934 as amended 1958 requires the involvement of the USFWS if the remedial alternative includes impoundment, diversion, channel deepening, or controlling or modifying a stream or body of water.

In 1998, MDCH adopted a new advisory protocol for women of childbearing age and children less than 15 years old (MDEQ 2006), based on the sport fish consumption advisory issued by the Great Lakes Sport Fish Advisory Task Force (GLSFATF) and presented in “Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory” (GLSFATF 1993). MDCH’s fish consumption advice, which is specific to various state water bodies (including the Kalamazoo River) by fish species and fish length, is published annually in *The Michigan Family Fish Consumption Guide* (MDCH 2012).

2.3.3 Action-Specific ARARs and TBCs

Action-specific ARARs include requirements for working in navigable waterways, handling and disposing of PCBs and hazardous waste (including transportation and disposal, permitting, manifesting, and disposal and treatment facilities), and general health and safety requirements. Action-specific ARARs also cover air emissions, dam construction/removal and management, discharge of fill and dredged materials, and discharge of processed water. Action-specific ARARs and TBCs applicable to Area 1 are presented in Table 2-3 and are summarized in the subsections below.

2.3.3.1 Navigable Waters, Lakes, Streams, and Wetlands-Specific ARARs

Federal location-specific ARARs contained in CWA 301, CWA 401, and CWA 404. CWA 301 and CWA 401 (as regulated by 40 CFR Parts 231 and 320–330) pertain to any federally authorized activity that may result in any discharge into navigable waters, and require reasonable assurance that the action will comply with applicable water quality standards. The provisions of CWA 404 would require acquisition of a permit to discharge dredged materials into navigable waters. In addition, the Rivers and Harbors Appropriation Act of 1899 (regulated by 33 CFR Parts 320-330) prohibits unauthorized obstruction or any alteration of any navigable waters in the United States. If in-stream excavation or capping activities are performed, requirements for permits for affecting navigable waters of the United States may apply.

State regulations are also in place to protect inland lakes, streams, and wetlands. Part 301 of NREPA regulates dredging or filling of lake or stream bottoms. Part 303 establishes the rules regarding wetland uses and the permit application process for protection of state wetland areas.

2.3.3.2 Identification and Management of Hazardous Materials ARARs/ Disposal and Storage ARARs

Regulations regarding identifying and listing hazardous wastes are pursuant to RCRA and outlined in 40 CFR Parts 260 to 264 and Part 115 (Solid Waste Management Regulations) of NREPA. 40 CFR Part 260 contains RCRA regulations governing identification, classification, generation, management, and disposal of hazardous waste. 40 CFR Part 261 defines threshold levels and criteria to identify whether a material is hazardous waste. 40 CFR Parts 262 and 263 identify standards applicable to generators and transporters of hazardous waste, respectively. Operators of Hazardous Waste Treatment and Disposal facilities are governed by 40 CFR Part 264. Part 115 establishes rules for solid waste disposal facilities.

Federal regulations for the transport and handling of hazardous materials are provided under 49 CFR Parts 107 and 171–172, 40 CFR Part 263, and the elements of Part 111 of NREPA related to handling and transportation requirements may also apply. The rules under 49 CFR include procedures for packaging, labeling, manifesting, and transporting hazardous materials and would potentially apply to the transport of hazardous materials from Area 1 for remedial alternatives that include offsite disposal of excavated materials. 40 CFR Part 263 sets standards that apply to transporters of hazardous waste within the United States if the transportation will require a manifest under 40 CFR Part 262.

Management of hazardous waste including record-keeping requirements is pursuant to the Solid Waste Disposal Act of 1965 as amended in 1976 (SWDA) and outlined in 40 CFR Parts 262 through 265, which include standards applicable to generators, transporters of hazardous waste, and standards for owners and operators of hazardous waste treatment and storage facilities. Land disposal restrictions, which regulate the management and disposal of PCBs, are also pursuant to the SWDA and are listed under 40 CFR Part 268.

Although ARARs associated with RCRA are listed above, listed hazardous wastes have not been identified and wastes classified as hazardous by characteristic are not anticipated. Analysis using the toxicity characteristic leaching procedure (TCLP) may be performed on excavated materials before transport to confirm the nonhazardous classification.

Federal regulations under TSCA govern disposal restrictions for substances such as PCBs. TSCA (as regulated by 40 CFR Part 761.50) identifies disposal requirements for various PCB waste types. TSCA (as regulated by 40 CFR Part 761.61) specifies cleanup and disposal options for PCB remediation waste including sediment and dredged materials. TSCA (as regulated by 40 CFR Part 761.65) establishes technical requirements for temporary storage of PCB wastes prior to treatment or disposal. TSCA (as regulated by 40 CFR Part 761.79) provides decontamination standards and procedures for removing PCBs that are regulated for disposal from water, organic liquids, and other materials.

CWA 401(b) and 501(a) (as regulated by 40 CFR Part 230) are TBCs which provide guidelines for specification of disposal sites for dredged or fill material. USEPA's *Evaluation of Dredged Material Proposed for Discharge in Waters of the U.S. Testing Manual* (EPA 823-B-98-004) is also a TBC which establishes the procedures for identifying the potential for contaminant-related impacts associated with discharge of dredged material in inland waters.

2.3.3.3 Discharge ARARs

Federal regulations under multiple sections of the CWA as regulated by 40 CFR Parts 403 and 136 establish responsibilities of federal, state, and local government, industry, and the public to implement National Pretreatment Standards to control pollutants that pass through or interfere with treatment processes in publicly owned treatment works (POTW). If water is treated during remedial action and discharged to a POTW, the influent requirements of these facilities must be met prior to discharging to the POTW, as prescribed 40 CFR Parts 136 and 403. These regulations also provide guidelines establishing test procedures for the analysis of pollutants.

In addition, 40 CFR Part 231 and 33 CFR Parts 320–330 apply to all existing, proposed, or potential disposal sites for discharges of dredged or fill materials into waters of the United States.

At the state level, the water bureau within MDEQ has responsibility for administering the National Pollutant Discharge Elimination System program under the authority of the CWA and Part 31 of NREPA. The Water Quality-based Effluent Limit Development for Toxic Substances (Part 8 of 31) and Wastewater Discharge Permit Requirements (Part 21 of 31) are applicable if the potential remedial alternative for Area 1 results in discharges to surface water. Part 22 is relevant if remedial activities involve discharge of waters or waste to groundwater or the ground.

2.3.3.4 Air Release ARARs

Potential remedial alternatives may result in primary or secondary releases of COCs or fine particulates into ambient air. Air quality standards to protect public health are covered under the Clean Air Act of 1963 as amended in 1970 (CAA) as regulated by 40 CFR Part 50. 40 CFR Part 52 establishes filing requirements and standards for constituent emission rates in accordance with the National Ambient Air Quality Standards.

At the state level, Part 55 of NREPA (Michigan Air Pollution Act) is an ARAR. This regulation establishes performance standards, filling requirements, and rules prohibiting the emission of air contaminants in quantities that can cause harmful effects to human health, animal life, plant life, and/or property.

2.3.3.5 Safety ARARs

Remedial action conducted in Area 1 must comply with applicable requirements outlined under the Occupational Safety and Health Administration (OSHA). General industry standards are outlined under 29 CFR 1910, which sets 8-hour, time-weighted average air concentrations for particulates and PCBs for protection of worker breathing zones. OSHA also establishes personal protective equipment (PPE), medical monitoring, and HAZMAT training requirements for workers involved with hazardous waste operations as specified under 29 CFR 1926. Record-keeping and reporting-related regulations are outlined under 29 CFR 1904.

At the state level, the Michigan OSHA (MIOSHA) Act 154 of 1974 establishes the rules for safety standards in the work place. Where applicable, any remedial action must follow certain provisions of MIOSHA that are more stringent than the counterpart federal OSHA requirements. Local traffic or noise ordinances may apply to remedial actions in certain sections of Area 1.

2.3.3.6 Management and Design ARARs

Pursuant to several sections within the CWA as regulated under 40 CFR 122 and 125, the potential remedial activity must employ the best available technology and monitoring and must specify best management practices. 40 CFR 125 establishes criteria and standards for imposing technology-based treatment requirements.

2.3.3.7 Fish and Wildlife-Specific ARARs

The Water Resources Development Act of 1986 as amended in 2007 and 2013 requires the involvement of the U.S. Army Corps of Engineers (USACE) to develop mitigation plans to repair fish and wildlife damage associated with remedy implementation.

2.3.3.8 Other Action-Specific TBCs

USEPA Sediment Remediation Guidance (USEPA 2005b) discusses sediment investigation procedures, remedial technologies, LTM, and the use of site-specific risk-based decision-making.

2.4 PRGs

As part of the BHHRA completed in 2003 (CDM 2003b), CDM developed a series of RBCs for fish, sediment, and floodplain soil (CDM 2003b) that were intended to be protective of anglers, recreationists, and residents. The site-wide BERA and Area 1 TBERA also developed RBCs for sediment and floodplain soil intended to be protective of sensitive wildlife receptors. The RBCs are calculated, chemical-specific concentrations below which no significant health effects are anticipated for a receptor. For human receptors, Site RBCs correspond to a target risk (TR) for carcinogenic effects (1×10^{-5}) and a target hazard index (THI) of 1 for noncarcinogenic effects. For ecological receptors, RBCs correspond to a target HQ (THQ) of 1. RBCs for ecological receptors represented a risk range based on NOAEL and LOAEL risk estimates for each receptor group. RBCs were calculated for total PCBs, which have been determined to be the primary risk driver in the BHHRA, BERA, and TBERA (see Section 1.3 for risk assessment summaries).

The calculation of RBCs is a tool for selecting PRGs. PRGs are numeric cleanup goals sufficient to protect human health and the environment and comply with ARARs. PRGs are the targets for the analysis and selection of long-term remedial goals.

2.4.1 Methodology for the Development of Fish RBCs

The risk-based concentrations for fish tissue (RBC_{fish}) were developed by reverse calculation of the risk assessment equations used to estimate the systemic hazards or cancer risk for anglers exposed to PCBs via the fish ingestion pathway. Using the TR and THI as the starting point, risk calculations were solved in reverse to estimate acceptable concentrations of PCBs in the edible portions of fish tissue. The same assumptions regarding ingestion rates (227 grams per fish meal), fraction ingested from Area 1, reduction factors from cooking (50 percent), body weight, averaging time, exposure frequencies (meals per year), exposure durations (years), and toxicity values for total PCBs listed in Appendix B of the BHHRA (CDM 2003b) were retained in the RBC_{fish} analysis. The RBC_{fish} are linked to each of the three receptor categories addressed in the BHHRA, namely the Sport Angler-Central Tendency (24 meals per year), Sport Angler- High

End (125 meals per year), and the Subsistence Angler (179 meals per year). A summary of the RBC_{fish} for each receptor is provided in Table 2-4. Equations and calculations used for RBC_{fish} determination are located in Appendix B of the BHHRA (CDM 2003b). The RBC_{fish} presented in Table 2-4 are not lipid-corrected values and are not species-specific. A mixture of species (e.g., 76% smallmouth bass and 24% carp) or one species (e.g., 100% smallmouth bass) may be ~~ingested; however, the overall intake of PCBs from fish tissue from Area 1 should not exceed the RBC_{fish} to be protective of human health.~~

Table 2-4. Risk-Based Fish Fillet Concentrations (RBC_{fish}) (CDM 2003a)

Receptor/Scenario	RBC_{fish} (based on 1 x 10^{-5} Cancer Risk) (mg/kg)	RBC_{fish} (based on HQ=1 Hazard Quotient) (mg/kg)
Sport Angler – Central Tendency	0.109	0.187
Sport Angler – High End	0.042	0.072
Subsistence Angler	0.015	0.025

ingested; however, the overall intake of PCBs from fish tissue from Area 1 should not exceed the RBC_{fish} to be protective of human health.The RBC_{fish} values presented in Table 2-4 are conservative values based on assumptions ranging from a worst-case scenario (i.e., subsistence angler) to a more typical risk exposure scenario (i.e., the central tendency sport angler). These values are also conservative because the exposure scenario assumes that the receptor ingests only fish from Area 1.The value for fish tissue above represents concentrations in edible portions of the fish (fillet tissue only) because this is the preferred preparation of anglers prior to consumption.

RBCs are only one tool used in the analysis of a PRG. Background fish tissue concentrations may also be considered in the selection of a PRG. Background concentrations are representative of levels entering Area 1 from an upstream source and are not attributed to Site activities. Remediation below background levels would not be practicable because reductions achieved below background would be temporary and would eventually rebound and come to equilibrium with background.

2.4.2 Reference Area (Background) Fish Concentrations

Background fish tissue concentrations were evaluated for three potential reference areas: ABSA-01, ABSA-02, and ABSA-03. ABSA-01 represents the Kalamazoo River upstream of the city of Battle Creek. ABSA-01 fish tissue samples were collected primarily in Ceresco Reservoir, which is more than 30 river miles upstream of the start of Area 1. ABSA-02 starts just upstream of the city of Battle Creek and spans Morrow Lake to the Morrow Lake Dam. ABSA-02 fish tissue samples were collected in Morrow Lake, which is immediately upstream of Area 1 (Figure 1-2). ABSA-03 spans the first 6.5 river miles of Area 1 from Morrow Lake Dam to Mosel Avenue (Figure 1-2). Fish tissue samples designated as being collected downstream of the Portage Creek confluence, ~~referred to~~i.e., identified as having been collected at sampling station ABSA~~-3~~-03.5~~ in Section 1.0~~, were excluded in this analysis~~. However, some fish tissue data collected in Area 3 downstream of the Portage Creek confluence may be included in this analysis, where a specific collection location in ABSA-03 was not available.~~.. At the request of MDEQ, ABSA-03 was evaluated as a potential reference area because it is the most upstream ABSA within Area 1 and represents free-flowing conditions and habitat similar to ABSA-04 and ABSA-05 that are also located within Area 1.

The Ceresco reservoir sampling area in ABSA-01 represents a similar lacustrine habitat to ABSA-02 (as opposed to the free-flowing conditions in Area 1) ~~but~~and is much farther upstream (30 miles~~) and therefore less representative of the conditions in Area 1 than ABSA-02.~~). The habitat of ABSA-02 is immediately upstream and is physically separated by Morrow Lake Dam from the paper mill-related PCB sources affecting Area 1 fish. PCBs in surface water and sediment in ABSA-02 reflect similar background inputs from atmospheric deposition or other upstream sources that affect Area 1. ~~In addition, the characteristics of sediment in Morrow Lake will define future ecological risk in Area 1 as that sediment is transported into Area 1 during high flow events and accumulates in Area 1 over time.~~ ABSA-03 has a free-flowing environment that is typical of Area 1, but is not representative of background exposure conditions. ABSA-03 spans Area 1 Sections 1, 2, and 3: Section 3 has been impacted by former paper recycling-related PCBs. Therefore, ABSA-03 was not selected as an appropriate background or reference area.

~~While no one reference area is a perfect match in habitat and hydraulic conditions, ABSA-02 appears to be most representative for use as a background area for comparison against current and projected Site fish tissue concentrations. Reference area ABSA concentrations should be selected to represent background conditions not impacted by releases from the Site. PRGs for Area 1 should not be set lower than PCB concentrations in the reference area and, in particular, the concentrations in Morrow Lake that are directly upstream of Area 1.~~

2.4.2.1 Fish Data

Fish have been collected and analyzed for PCBs in the reference ABSAs over several years for three categories of fish tissue:

- Smallmouth bass fillets in 1993, 1997, 1999, 2000, 2001, 2006, 2009, and 2012
- Smallmouth bass YOY whole-body composites in 1999, 2000, 2001, and 2006
- Carp fillets in 1993, 1997, 1999, 2000, 2001, 2006, 2009, 2011, and 2012

Fish PCB data from the reference area were treated in the same manner as fish collected in Area 1 (Section 1.3.1). As representative of more current conditions, fish concentration trends were calculated using data from 2006 to 2012 (see Appendix D). The methods and dataset for statistical analyses of each fish tissue category in ABSA-01 and -02 are included in Appendix D. Figures depicting data and regression models are also included in Appendix D. These evaluations are discussed and presented for ABSA-03 in Section 1.3.1.3 and Appendix B.

Generally, smallmouth bass fish fillet tissue PCB concentrations declined in ABSA-01, but increased slightly in ABSA-02. No significant trend was observed in YOY smallmouth bass. Significant trends in carp fillet tissue were also not observed in ABSA-01; however, a decline in PCB concentrations in carp fillet tissue was observed in ABSA-02. This trending information suggests that sample collection for background fish tissue concentrations should continue so that future background concentrations may be compared to fish tissue concentrations in Area 1 after remediation.

2.4.2.2 RBC for Fish Tissue (RBC_{fish})

Based on protection of high-end sport anglers as the representative Site receptors, a risk-based concentration (RBC_{fish}) of 0.~~2~~042 mg/kg (non-lipid-corrected, carcinogenic risk of 10^{-5}) was previously calculated (Figure 2-1; CDM 2003). This also approximately corresponds to the fish advisory consumption level for women of childbearing age and children under age 15 eating ~~1 meal~~4 meals of fish per month (MDCH 2013).

2.4.2.3 Current Fish Tissue PCB Concentrations and Percent Lipids

Total PCB concentrations in fish tissue in the reference ABSAs were calculated using fish tissue samples from the most recent data collection events, which were 2006 for ABSA-01 and 2012 for ABSA-02. The following ranges of median total PCB concentrations were observed in fish tissue samples from ABSA-01 and -02 (Table 2-5):

- Smallmouth bass fillet: 0.026 to 0.23 mg/kg
- Smallmouth bass YOY whole body: 0.12 to 0.34 mg/kg
- Carp fillet: 0.13 to 0.34 mg/kg

The data provided in Table 2-5 also include mean and median total PCB concentrations from ABSA-03, for the data set described above in Section 2.4.2. Concentrations in fish tissue samples collected in ABSA-01 are less than the non-lipid-corrected RBC_{fish} of 0.~~2~~042 mg/kg for carcinogenic risk associated with the high-end sport angler~~ with a 100% bass diet~~, while concentrations of fish collected in ABSA-02 are equal to or greater than the RBC_{fish}. Overall fish tissue PCB concentrations just downstream of the Morrow Lake Dam in ABSA-03 are greater than those in ABSA-02.

2.4.2.4 Lipid-Corrected PCB Concentrations

Fish tissue PCB concentrations were lipid-corrected using the mean percent lipid for fish tissue in each reference ABSA (see Table D-2 for lipid percentages). For fish sampled from 2006–2012 in the reference area ABSAs, median lipid-corrected concentration ranges are as follows (Table 2-6):

- Smallmouth bass fillet: 4.6 to 27.0 mg/kg
- Smallmouth bass YOY whole body: 3.2 to 15.9 mg/kg
- Carp fillet: 7.3 to 19.4 mg/kg

2.4.3 Selection of Fish Preliminary Remediation Goals

The selection of a fish tissue PRG was a multi-step process that considered the RBC_{fish} values generated for each receptor, the likely exposure scenario to be frequently encountered, and the background levels of PCBs in fish tissue. Although a subsistence angler scenario was included in the calculation of RBC_{fish}, this pathway represents a worst-case scenario and an exposure pathway that is not expected to be frequently encountered compared to sport anglers. The RBC_{fish} would likely reflect a diet that is weighted toward the 100 percent smallmouth bass consumption scenario over a mixed carp and bass species scenario because the smallmouth bass is a popular sport fish on the Kalamazoo River. The range of RBC_{fish} for sport anglers is from 0.042 mg/kg to 0.187 mg/kg. The upper end of this range is similar to the mean background concentration in smallmouth bass fillets in ABSA 2, which is immediately upstream of Area 1 (0.~~2~~23 mg/kg). The upper end of this range is also protective of women of childbearing age and young children consuming one half-pound meal a month from the site (0.11 to 0.21 mg/kg). ~~Due to the highly conservative assumptions contained in the equations used to generate the RBC_{fish}, the low end of RBC_{fish} for the high-end sport angler likely contains an overestimation of risk.~~ The recommended fish tissue ~~PRG is, therefore,~~PRGs range from 0.~~2~~042 to 0.187 mg/kg, and are based on risk estimates to sports anglers, sensitive populations, and background considerations.

2.4.4 Methodology for the Development of Sediment RBCs

The RBC_{fish} were used to develop human health risk-based concentrations for sediment (RBC_{sed}) protective of sport and subsistence anglers who consume fish from Area 1. The

RBC_{sed} was calculated using the biota-to-sediment accumulation factor (BSAF) method. The BSAF method relates site-specific fish concentrations to site-specific sediment concentrations using the following relationship:

$$BSAF = (PCB_{fish} / \%lipid) / (PCB_{sed} / \%TOC)$$

Where:

PCB_{fish} = concentration of PCBs in fish fillet
%lipid = percentage of lipids in fish fillet
PCB_{sed} = concentration of PCBs in sediment
%TOC = percentage of total organic carbon in sediment

BSAFs were based on lipid-normalized fish fillet PCB concentrations and organic carbon-normalized sediment concentrations. Normalization of fish fillet and sediment concentrations is performed because the body burden of hydrophobic PCBs are found in the fatty tissues of fish, and the amount of organic carbon can influence the extent to which PCBs sorb to the sediment. Using site-specific BSAFs, the following equation was used to derive RBC_{sed}:

$$RBC_{sed} = (TOC*RBC_{fish}) / (BSAF*\%lipid)$$

Where:

TOC (site-wide mean) = 0.0279%
BSAF (site-wide mean) = 0.444 (bass); 0.641 (carp)
%lipid (site-wide mean) = 0.013 (bass); 0.0358 (carp)
RBC_{fish} = See Table 2-4

The equation for RBC_{sed} above is dependent on the percentage of lipids present in fish, and this value can vary by species. Bioaccumulation of PCBs from the sediment into fish tissue may also vary by species depending on life cycle characteristics. Bottom-dwelling species (e.g., carp) that are in close contact with sediment likely exhibit different bioaccumulation profiles from fish that reside in the water column (e.g., smallmouth bass) where PCB levels are lower. These factors can influence the RBC_{sed} values depending on whether a 100% smallmouth diet or mixed species diet is assumed. BSAFs and RBC_{sed} were calculated on a site-wide basis for the range of RBC_{fish} values and dietary scenarios developed in the BHHRA. Mean BSAFs were calculated for each of the seven ABSAs; however, the BSAFs did not differ greatly among ABSAs, and ABSA-to-ABSA differences likely represent variability in measurements and uncertainties in the BSAF model. Thus, for risk assessment purposes, pooled data from all ABSAs were used for final calculations of RBC_{sed}. Although the RBC_{sed} were developed using pooled site-wide data, the values are applicable to individual ABSAs as well. The full analysis and description of the BSAF is presented in CDM (2003). The calculated RBC_{sed} for human health receptors are summarized in Table 2-7.

Table 2-7. Human Health Risk-Based Concentrations for Sediment (CDM 2003b)

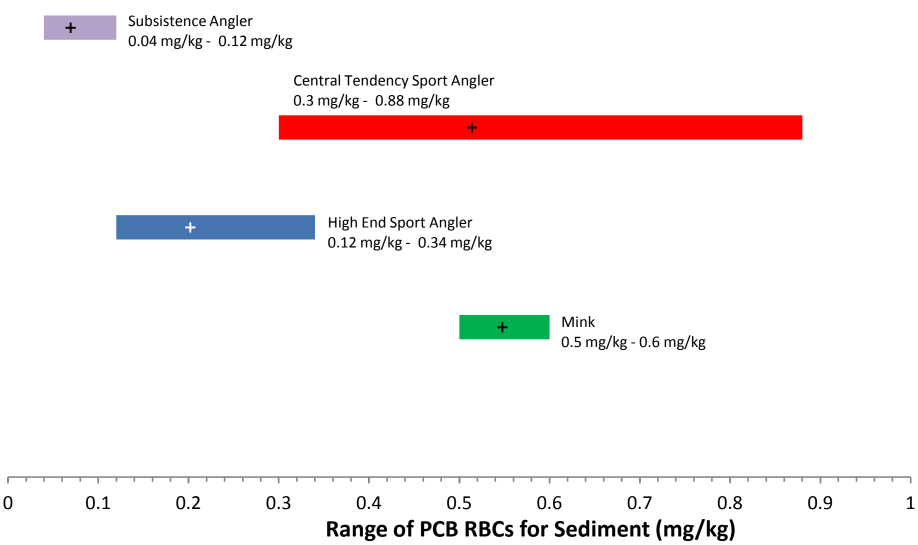
Receptor/Scenario	**RBC_{sed} (Protective of Fish Ingestion; Cancer Risk = 10^{-5}) (mg/kg)**		**RBC_{sed} (Protective of Fish Ingestion; HQ=1) (mg/kg)**	
Diet	**100% Smallmouth Bass**	**76% smallmouth bass/24% carp**	**100% Smallmouth Bass**	**76% smallmouth bass/24% carp**
Sport Angler –	0.51	0.30	0.88	0.52

Receptor/Scenario	RBC_{sed} (Protective of Fish Ingestion; Cancer Risk = 10^{-5}) (mg/kg)		RBC_{sed} (Protective of Fish Ingestion; HQ=1) (mg/kg)	
Central Tendency				
Sport Angler – High End	0.20	0.12	0.34	0.20
Subsistence Angler	0.07	0.04	0.12	0.07

The BERA (CDM 2003a), based on many of the same site data, also presented a range of RBCs based on ecological risk. The Site-Wide BERA concluded that PCBs in surface water and streambed sediment are likely to adversely affect sensitive piscivorous predators, such as the mink and bald eagle, through consumption of PCB-contaminated prey (predominantly fish) and through direct exposure. The mink was the most sensitive receptor to PCBs through exposure to prey items and sediment, and ecological RBCs protective of the mink, which range from 0.5 mg/kg (No Effects Level) to 0.6 mg/kg (Low Effects Level), and would be protective of the bald eagle, and other wildlife.

~~The range of RBC_{sed} based on protection of the mink is within the range of RBCs developed based on risks and hazards to human health as shown in Figure 2-1.~~

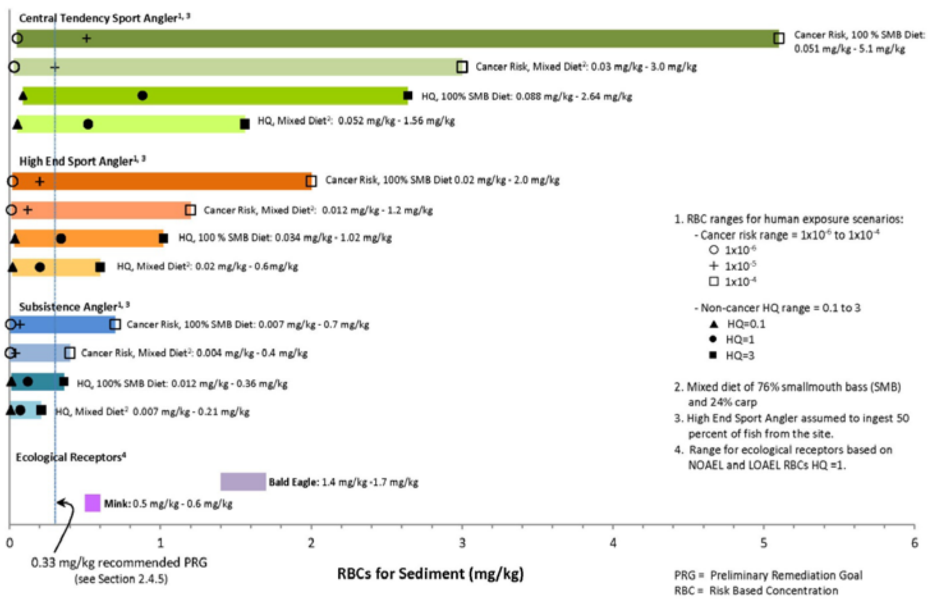
Figure 2-1
PCB RBCs Protective of Human and Ecological Receptors
Based on Risk from Fish Ingestion



+ Indicates the geometric mean.

The range of RBC_{sed} based on protection of ecological receptors and RBCs developed based on risks and hazards to human health are shown in Figure 2-1. The sediment RBC endpoint concentration ranges shown on Figure 2-1 for protection of human health from fish ingestion represent 10^{-6} to 10^{-4} cancer risk and non-cancer hazard indices of 0.1 to 3 calculated for each human exposure and fish diet scenario. RBC_{sed} concentrations associated with a range of carcinogenic risk (10^{-6} to 10^{-4}) and noncarcinogenic risk (HIs of 0.1 to 3) are provided as additional information for the risk manager. The specific concentrations within each range associated with target risk values are indicated. RBC_{sed} ranges for representative ecological receptors are included, with the mink representing the more conservative receptor (lower associated sediment concentrations) and the bald eagle representing an upper range.

Figure 2-1
PCB Sediment RBCs Protective of Human and Ecological Receptors
Based on Risk from Fish Ingestion



Like RBC_{fish}, RBC_{sed} are only one tool used in the analysis of a PRG. Background sediment concentrations should also be considered in the selection of a PRG. The background sediment concentration was determined using data from Morrow Lake (65 samples), Ceresco Reservoir (1 sample), and the area surrounding Battle Creek (1 sample) (see Appendix E). Data from the top 6 inches were included in the background data set as this interval is the most likely to come into contact with fish. After eliminating outliers, the arithmetic mean and 95% upper prediction limit (UPL) of the mean background surface sediment concentration were calculated using ProUCL to be 0.31 mg/kg and 0.81 mg/kg, respectively. The 95% UPL background sediment concentration falls ~~within~~in the ~~upper~~ range of RBC_{sed} near the $1x10^{-5}$ cancer risk and HI of 1 calculated for the central tendency sport ~~anglers~~angler with 100% smallmouth bass diet.

2.4.5 Selection of Sediment PRGs

The selection of a sediment PRG considered the human health RBC_{sed} values associated with the human receptors who consume fish. ~~The range of RBC_{sed} based on protection of the mink, the most sensitive ecological receptor, was within the range of human health RBCs. The recommended sediment PRG is 0.33 mg/kg for PCBs. This PRG represents the upper-bound range of RBC_{sed} for the high-end sport angler and the low end of the central tendency sport angler. A PCB PRG for sediment of 0.33 mg/kg would also be protective of ecological receptors.~~MDEQ has conducted an independent evaluation and has recommended a sediment of PRG of 0.33 mg/kg (Bucholtz, P., November 22, 2013 e-mail to Draper, C.). MDEQ concluded that this PRG value is appropriate for sediment because it is sufficiently protective the high-end sports angler. This PRG value also corresponds to the historical MDEQ PCB detection limit that has previously been used as a screening and target level in Michigan, and has become a precedent value in the state for PCB site cleanup efforts under Michigan NREPA Part 201. A PRG of 0.33 mg/kg falls below the RBC_{sed} risk ranges for ecological receptors and is at the lower end of the human health exposure ranges as shown on Figure 2-1. Specifically, this PRG is near (similar order of magnitude) or below the

- Central-tendency sport angler 10^{-5} carcinogenic risk value for the 100% bass diet and mixed fish diet
- Central-tendency sport angler noncarcinogenic risk HI value of 1 for the 100% bass diet and mixed fish diet
- High-end sport angler 10^{-5} carcinogenic risk value for the 100% bass diet and mixed fish diet
- High-end sport angler noncarcinogenic risk HI value of 1 for the 100% bass diet and mixed fish diet

This PRG value is also less than the corresponding sediment concentrations for the 10^{-4} risk level and HI of 3 for the subsistence sport angler. Based on the above evaluation and that conducted by MDEQ, sediment concentrations below 0.33 mg/kg are not likely to bioaccumulate in fish tissue to levels that present unacceptable risk and hazards to human populations ~~or wildlife~~, and will promote the achievement of the RAO for fish tissue over time.

The range of RBC_{sed} values for protection of the mink, the most sensitive ecological receptor, and the bald eagle are greater than the range of human health RBCs. Therefore, a sediment PRG that is protective of human health will also be protective of ecological receptors.

2.4.6 Methodology for the Development of Floodplain Surface Soil RBCs

The site-wide, risk-based floodplain soil concentrations (RBC_{soil}) were derived in the same manner as the RBC_{fish} (i.e., reverse calculation of the forward risk equations to a THI of 1 and a TR of 1×10^{-5}). The same exposure assumptions used to estimate risks and hazards were used to derive RBC_{soil} for residential and recreational receptors potentially exposed to floodplain soil surrounding the three former Michigan Department of Natural Resources (MDNR) impoundments. Calculations of the RBC_{soil} for noncarcinogenic hazards were performed separately for the two endpoints assessed in the BHHRA: reproductive effects and immunological effects. The equations and calculations used for the RBC_{soil} determination are located in Appendix B of CDM (2003).

The RBC_{soil} values presented in Tables 2-8 and 2-9 are ~~highly conservative~~reasonable maximum values based on assumptions ranging from a high-end exposure scenario (i.e., resident living next to the floodplain for 30 years) and a more typical risk exposure scenario (i.e., recreationist accessing the floodplains for hunting, picnicking, or bird watching).

Table 2-8 presents the RBC_{soil} for the residential receptors.

Table 2-8. Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Residents (CDM 2003b)

Receptor/Scenario	Age-Adjusted RBC_{soil} (1 x 10^{-5} Cancer Risk) (mg/kg)	RBC_{soil} (THI=1) (mg/kg)
Residential Receptor	2.5	15 (R – 2 to 7 years) 4.0 (I – 30 year exposure)

(R) = Reproductive Endpoint
(I) = Immunological Endpoint

Table 2-9 presents the RBC_{soil} for the recreational receptors.

Table 2-9. Risk-Based Floodplain Soil Concentrations (RBC_{soil}) Protective of Recreationists (CDM 2003b)

Receptor/Scenario	Age-Adjusted RBC_{soil} (10^{-5} Cancer Risk) (mg/kg)	RBC_{soil} (THI=1) (mg/kg)
Recreational Receptor	23	139 (R – 2 to 7 years) 32 (I- 30 year exposure)

(R) = Reproductive Endpoint
(I) = Immunological Endpoint

~~The Area 1 TBERA (ARCADIS 2012d), summarized in Section 1.3, also presented a range of surface soil RBCs based on ecological risk. The RBC_{soil} for ecological receptors considered both NOAEL and LOAEL effects. Overall, the Area 1 TBERA found no unacceptable risk to either carnivorous birds and mammals or low- to moderate-sensitivity birds. PCB concentrations remaining in the floodplains of the former Plainwell Impoundment and Plainwell No. 2 Dam Area following completion of the TCRA projects are below levels that might present risks to carnivorous mammals and low- or moderately sensitive species of birds. Potential risk was identified for vermivorous mammals (represented by the short-tailed shrew) in localized areas. Potential, but inconclusive, risk was also identified for high-sensitivity insectivorous birds and vermivorous birds (i.e., birds with greater than 40 percent worms in diet); however, this class of birds has not been observed at the Site. Table 2-10 presents the RBC_{soil} calculated for ecological receptors.~~

The Area 1 TBERA (ARCADIS 2012d) presented a range of soil RBCs for terrestrial receptors. Table 2-10 presents a summary of the potential RBC_{soill} for ecological receptors. Figure 2-2 presents the range of RBCs calculated for each wildlife receptor, which generally are within the range of RBC_{soil} calculated for the residential and recreational receptors.

Table 2-10. RBCs for Floodplain Soil in mg/kg Total PCB (ARCADIS 2012d)

~~**Table 2-10. Ecological Risk-Based Floodplain Soil Concentrations (RBC_{soil}) (CDM 2003a)**~~

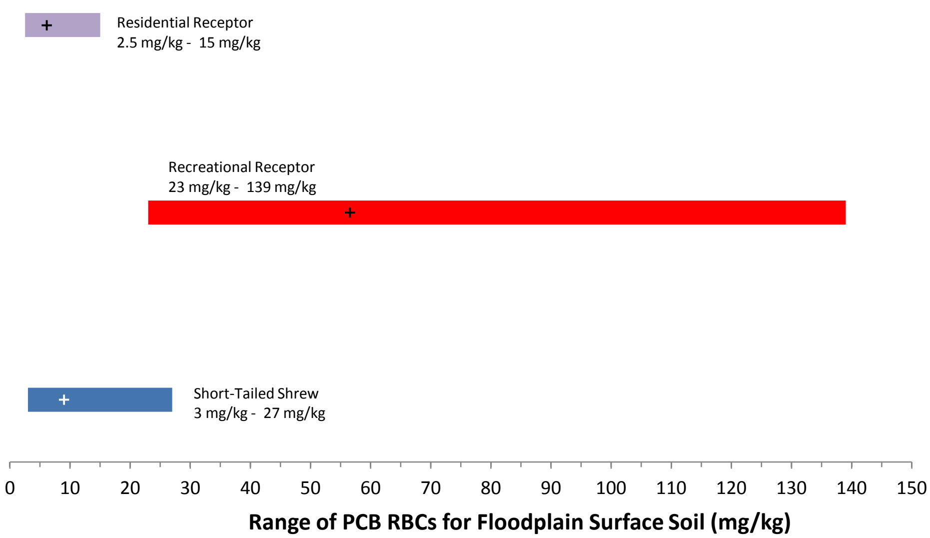
	~~Exposed Sediment/Floodplain RBC_{Soil} (mg/kg)~~	
	~~NOAEL-Based RBC~~	~~LOAEL-Based RBC~~

~~Birds* (High Sensitivity)~~	~~0.2 – 30~~		~~0.5 - 38~~	
~~Birds* (Mid-Range Sensitivity)~~ Receptor	~~7 – 46~~High Sensitivity TRVs NOAEL	LOAEL	~~20 – 137~~Mid-Range Sensitivity TRVs NOAEL	LOAEL
Approach 1 - Total PCBs				
American robin	13	16	19	56
American woodcock	4	5	7	20
House wren	16	20	23	70
Red-tailed hawk*	29	38	44	137
~~Vermivorous Mammals~~Shrew	~~3 –~~6	18~~– 27~~	--	--
~~Carnivorous Mammals~~ Fox*	17~~– 18~~	~~51 –~~ 54	--	--
Approach 1 - TEQs				
Shrew	3	27	--	--
Approach 2 - Total PCBs				
Birds	1	2	43	62
Approach 2 - TEQs				
Birds	0.3	1	32	65
Approach 3 - TEQs				
American robin	0.2	0.5	17	35

~~*Bird RBCs include insectivores, vermivores, and carnivores.~~ * Range of NOAEL-and LOAEL-based RBCs presented for these species based on use of different BAF approaches.

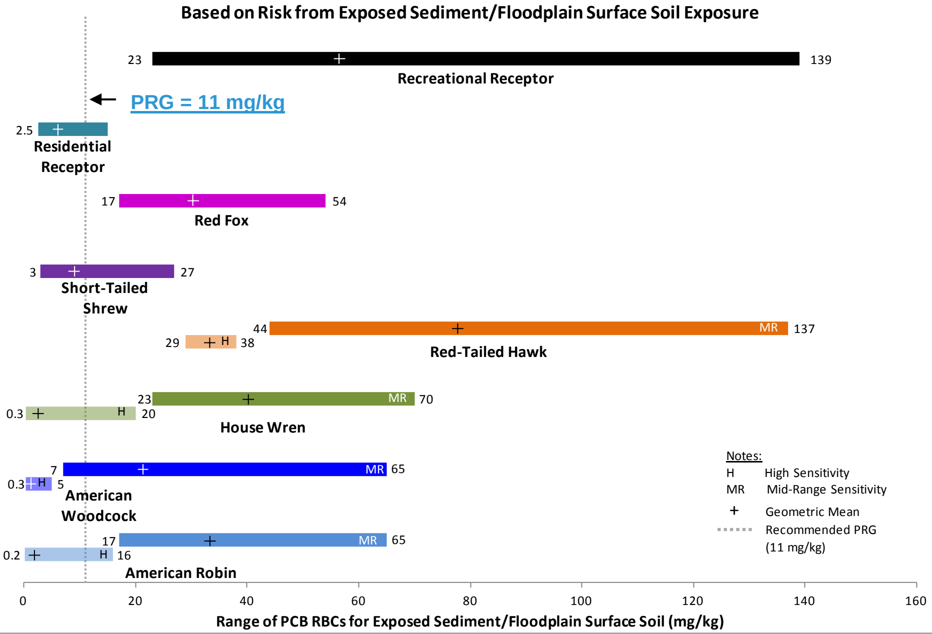
~~Unacceptable HQs were primarily associated with vermivorous mammals (i.e., the short-tailed shrew), although a range of RBC$_{soil}$ was calculated based on protection of multiple wildlife receptors. The RBC$_{soil}$ for the short-tailed shrew is generally within the range of RBC$_{soil}$ calculated for the residential receptor as shown in the Figure 2-2.~~

Figure 2-2
PCB RBCs Protective of Human and Ecological Receptors Based on Risk from Floodplain Surface Soil Exposure



+ Indicates the geometric mean.

Figure 2-2
PCB RBCs Protective of Human and Ecological Receptors
Based on Risk from Exposed Sediment/Floodplain Surface Soil Exposure



2.4.7 Selection of Floodplain Surface Soil PRGs

The selection of a floodplain surface soil PRG was based on the range of site-specific RBC_{soil} values calculated for ~~terrestrial mammals~~human and ~~human receptors. The lowest RBC_{soil} values were observed for the residential receptor and the short-tailed shrew. Due to the highly conservative assumptions in the equations used to generate the RBC_{soil}, the low end of RBC_{soil} for the residential receptor likely assumes an overestimation of exposure and associated risk. The~~ ecological receptors. The representative RBC_{soil} for ~~this receptor~~ human receptors likely falls somewhere within the range of the calculations presented. ~~The range of RBC_{soil} for the short-tailed shrew was also calculated using conservative exposure assumptions; however, due to the small home range of this receptor and~~ Although ecological risk was predominantly associated with high ~~rate of soil contact, the PRG for floodplain surface soil was selected to be protective of this receptor in particular. With consideration of the conservative nature of the exposure assumptions used in the HHRA, BERA, and~~ sensitivity insectivorous and vermivorous birds and vermivorous mammals in the Area 1 TBERA, ~~the recommended~~ a range of RBC_{soil} was calculated based on the protection of multiple wildlife receptors (Table 2-10 and Figure 2-2). A detailed analysis of the uncertainty associated with the TBERA RBCs is provided in Attachment 1 of Appendix G. These uncertainties are summarized below.

In the selection of floodplain soil PRGs, RBCs for the shrew were evaluated because this receptor has a relatively high ingestion rate, small home range, and high rate of dietary soil exposure due to a high percentage of soil invertebrates in its diet compared to other small mammals. The TEQ RBCs for the shrew are considered more uncertain than the total PCB-based RBCs because the RBCs for TEQs include an additional modeling step over the total PCB RBCs.

RBCs for high sensitivity birds were also evaluated in the selection of floodplain surface soil PRGs. RBCs calculated using the dietary approach (Approach 1) are considered relatively more certain than the egg-based approaches (Approaches 2 and 3), as discussed in Section 1.3.3.4.

Additional uncertainty associated with the avian risk characterization and subsequent RBCs was also evaluated in the selection of floodplain surface soil ~~PRG~~ PRGs. Recent research published following preparation of the Area 1 ASTM (ARCADIS 2012b) indicates that the relative sensitivity of avian receptors is ~~11 mg/kg for PCBs. This PRG is~~ more complex than the simple classification of high, moderate, and low sensitivity. Manning et al. (2013) suggests there is no simple ratio of species sensitivity between the ~~geometric mean and the arithmetic mean of the~~ classifications based on the AhR structure and that the relative sensitivity is also affected by the mix of congeners present. As such, the sensitivity of avian species to PCBs may be site-specific. The Area 1 TBERA (ARCADIS 2012d) and Area 1 ASTM (ARCADIS 2012b) do not discuss this uncertainty; however, this uncertainty is considered in the FS characterization of current conditions and relative risk reduction of the various alternatives.

The range of RBCs from the Area 1 TBERA, as shown in Figure 2-2, were used to select an appropriate floodplain soil that would be protective of the range of ecological receptors. Based on the analysis presented in the Area 1 ASTM (Appendix G) and the current post-TCRA conditions at the former Plainwell Impoundment, a PRG of 11 mg/kg is shown to be protective of 82% of the possible 1-acre home ranges for maximally exposed mammalian receptors (i.e., the shrew). Current post-TCRA conditions at the Plainwell No. 2 Dam Area are 100% protective of the possible 1-acre shrew home ranges. A PRG of 11 mg/kg PCBs is also assumed to be protective of avian receptors as it represents a balance between risk and uncertainty associated with the various methodologies and assumptions used in the TBERA to calculate risk to avian receptors. A PRG of 11 mg/kg is below the dietary high sensitivity RBCs calculated for the house wren and American robin and within the mid-range ~~of RBC_{soil} determined~~and high sensitivity dietary RBCs calculated for the American woodcock. For the American woodcock, a PRG of 11 mg/kg is within the mid-range sensitivity dietary RBCs and above the high sensitivity dietary RBCs. A PRG of 11 mg/kg falls between the egg-based RBCs for ~~the short-tailed shrew~~mid-range and high sensitivity avian receptors. Evaluation of the dietary and/or egg-based RBCs calculated for the ecological receptors indicates that the proposed PRG of 11 mg/kg in floodplain soil is protective of various ecological receptors. The ~~selected RBC_{soil} is~~ PRG of 11 mg/kg is also within the RBC range for residential receptors,and is considered to be protective of recreational receptors~~ (Table 2-9).~~.

2.5 GENERAL RESPONSE ACTIONS

General Response Actions (GRAs) represent the types of remedial responses available for impacted media to meet RAOs. The GRAs for Area 1 sediment and floodplain soil include:

- **No Action**, as mandated by CERCLA, includes no new remedial measures. According to the NCP, 40 CFR 300.68, No Action is retained for detailed analysis and used as a baseline in comparing alternatives.
- **Monitored Natural Recovery (MNR**) involves actively monitoring the progressive reduction, isolation, or sequestration of COCs in media of concern due to natural physical, chemical, and biological processes that break down or reduce contaminant concentrations or availability over time. Options for enhancing MNR may also be

considered, such as thin-layer capping to augment naturally occurring sediment deposition processes.

- **Institutional Controls (ICs)** are intended to restrict exposure to impacted media. ICs can include extended monitoring, land use restrictions, and restrictions on fish consumption. ICs do not reduce constituent concentrations or protect ecological receptors. ICs, as a stand-alone remedial action, are appropriate where there is significant natural recovery, where constituents are immobile, where the risk assessment does not identify constituents as potential future hazards, where the costs to implement remedial measures outweigh the benefits, or where the short-term risk to implement a technology outweighs the benefit. ICs, including but not limited to deed/land use restrictions and fish consumption advisories will be considered for Area 1 in combination with other remedial technologies.
- **Engineering Controls (ECs)** are intended to limit exposure of receptors to impacted media. ECs do not reduce constituent concentrations or protect ecological receptors. ECs typically include fencing, posting of warning signs, placement of physical barriers, security measures, and other physical structures that would restrict human receptors. Other examples include erosion control measures to prevent erosion and downstream migration of impacted media. ECs will be considered for Area 1 in combination with other remedial technologies.
- **Containment** includes preventing direct exposure to the impacted media and limiting constituent mobility. Containment technologies do not reduce toxicity or volume. Long-term, in-place management would be required with a long-term monitoring program. Examples of sediment containment are in situ capping, natural or enhanced sedimentation, and rechannelization (e.g., permanently diverting flow around a portion of an existing channel) to isolate impacted media.
- **Removal** involves dredging or excavation of impacted sediment or floodplain soil followed by either on-site or off-site treatment and/or disposal to reduce risk. Removal does not provide treatment or reduce toxicity; therefore, it must be combined with treatment and/or disposal. Dredging of wet sediment may result in incomplete sediment removal due to sediment resuspension during dredging and remaining residuals. While the mass of impacted material may be reduced, risk may or may not be reduced to acceptable levels. Short-term to moderate-term adverse effects to be considered include an increase in sediment suspension and remobilization of PCB-containing material, followed by an increase in concentrations in fish during removal; or the destruction of habitat to achieve contaminant removal goals for ecological risk.
- **Disposal** of dredged/excavated sediment or excavated soil can be accomplished by removal to an off-site facility. Dewatering, stabilization, and/or treatment of recovered material may be required prior to disposal. Off-site disposal would involve transporting nonhazardous sediment and/or soil to an approved, permitted landfill.

3.0 TECHNOLOGY IDENTIFICATION/SCREENING AND ALTERNATIVE DEVELOPMENT

3.1 REMEDIAL TECHNOLOGY IDENTIFICATION AND SCREENING

This section presents the evaluation of GRAs, technologies, and process options applicable for Area 1 consistent with the requirement of Task 5.1.3 of the SOW. The remedial technologies and corresponding process options for sediment and floodplain soil are presented in Table 3-1 and Table 3-2, respectively. Technology types are general categories of technologies, while process options refer to specific processes within each technology type (USEPA 1988a). For example, dredging is a technology type under the more general sediment removal GRA, and mechanical and hydraulic dredging are process options under dredging. The following sections describe each technology and identify those retained for further evaluation.

The remedial technologies and process options were screened based on the criteria of overall effectiveness, implementability, and relative cost as established by USEPA Guidance (USEPA 1988a). In addition, the technologies and corresponding process options were screened based on their technical merit relative to other available technologies. This screening process identified those technologies that are the most applicable and feasible.

The results of this evaluation are used to select representative process option(s) for each technology type for Area 1, which are then used to assemble potential sediment and floodplain soil alternatives. The screening criteria used in this evaluation are described below.

- **Criterion 1: Implementability**

  Implementability addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and material required during its implementation. This criterion involves: 1) technical feasibility (construction, operation, reliability, ease of undertaking, and monitoring), 2) administrative feasibility (coordination among agencies for such items as permitting), and 3) availability of services and materials (treatment/disposal services, equipment, specialists, provisions, and technologies) (USEPA 1988). The evaluation of implementability considers the conditions and characteristics of Area 1 that would potentially limit or challenge the use of a particular technology or process option, along with considerations such as permit equivalency requirements; the availability of treatment, storage, and disposal services (including capacity); and the availability of necessary equipment and skilled workers to implement the technology.

- **Criterion 2: Effectiveness**

  Effectiveness is based on the ability of the technology and process option to meet the RAOs, the potential impacts to human health and the environment during the construction and implementation phase, and the reliability of the technology to address PCBs in Area 1. Overall effectiveness considers short-term effectiveness during remedial action and long-term effectiveness after the remedial action is completed. Remedial alternatives that do not meet RAOs were not considered for detailed analysis, with the exception of the No Action technology, which is required by USEPA as a baseline condition.

- **Criterion 3: Relative Cost**

  A relative cost evaluation is performed qualitatively at this stage (i.e., high, medium, low), based on engineering judgment and site-specific information. The overall cost for implementing a particular process option is evaluated relative to other options within the same technology group. Considerations include the capital, implementation, and maintenance expenditures.

3.1.1 Sediment Technologies Evaluation

Sediment remediation technologies and process options were evaluated to reject those that are less viable and/or not applicable. The results of this screening are presented in Table 3-1. The following technologies/process options were retained to develop sediment remedial alternatives:

- No Further Action
- MNR
- Institutional Controls (ICs)/Engineering Controls (ECs)
- Removal of impacted sediment (dredging, excavation)
- Treatment (dewatering and/or addition of conditioning amendments to dredged or excavated sediment)
- Disposal (on-site or off-site landfill)

The sediment remediation technology screening analysis is summarized below.

3.1.1.1 No Further Action

No Further Action was retained as required by the NCP to be used as a baseline against which other sediment alternatives will be evaluated. Typically, this process option is described as No Action, but because extensive source control efforts were completed or, as with the current USEPA removal action in Portage Creek, are ongoing in and adjacent to Area 1 (see Section 1.3.4), it is appropriate to refer to this process option as No Further Action. While ongoing natural recovery processes drive the effectiveness of this process option in achieving RAOs, the reductions in exposure and risk achieved through ongoing natural recovery processes would not be tracked through monitoring.

3.1.1.2 MNR

MNR was retained as a GRA because USEPA (2005) recognizes MNR as one of three major remedial approaches available for managing risks associated with contaminated sediment and supports combining approaches to attain protection of human health and the environment, especially at large, complex sites. Ongoing natural recovery processes in Area 1 would be tracked through implementation of an LTM program. In 1998, MDEQ initiated an LTM program for the Site that includes collection of fish tissue samples and surface water data. This LTM program could be modified/expanded as part of a remedy for Area 1.

3.1.1.3 Enhanced MNR

Enhanced sedimentation (via dams or other engineered structures) was considered but not carried forward to the assembly of sediment alternatives, because the construction of structures needed to facilitate higher rates of sedimentation would be in opposition to restoring the free-flowing conditions created through the removal of the Plainwell Dam. The former Plainwell Dam was removed, and the remaining structures (the two Plainwell No 2. diversion structures) are unmaintained remnants. Thin-layer capping was considered but not retained as a technology option; most of Area 1 is not suitable for sediment cap installation because the majority of this area is a free-flowing river channel, conducive to transporting thin cap layers during flooding events. The purpose of this thin-layer cap is to add a layer of clean material as a starting point to reduce the time to reach cleanup goals using natural processes such as deposition of clean sediment.

3.1.1.4 ICs

Under ICs, fish consumption advisories were retained as a representative process option. It is anticipated that fish consumption advisories currently in place and maintained by MDCH would remain in place until the State agencies determine that they can be revised or removed. The current advisories include the recommended fish consumption limitations and exclusions for various species collected between Morrow Dam and Lake Allegan Dam. Retained ICs would be applied in combination with other remedial technologies.

3.1.1.5 ECs

ECs that were retained during screening are the posting of warning signs and erosion controls for the riverbank. Engineering controls may include armoring, vegetation, and grading. These controls would be applied in combination with other remedial technologies. Signage is already in place at river access points in Area 1 and is maintained by MDEQ. Sediment armoring techniques could be deployed to protect riverbanks from erosion. Fencing was also considered as an EC but deemed impractical, and was not retained.

3.1.1.6 Sediment Containment

Installing an in situ sediment cap would reduce potential risks associated with exposure to PCB-containing sediment over the long term through physical and/or chemical isolation. While some temporary impacts to the benthic organisms and habitat would likely occur, it is expected that the benthic community would recover quickly. Design considerations that must be evaluated to fully assess the effectiveness of a capping remedy are erosional forces from water flow during both high flow/flooding events and normal flows, particularly given the shallow water depths and moderate flow velocities typical for much of the year.

Water depths are also important because they define the maximum allowable thickness of a cap and identify the potential for cap erosion due to ice scour and wind-induced waves. Water depths are also important to define the recreational usability of an area following construction of the cap (because a cap could be compromised by, for example, prop wash). Impacted sediment areas that are located in side channels would be most suitable for cap placement. Sediment capping was retained as an option for these areas. Capping is an accepted and approved approach for managing potential risks posed by contaminants of concern in sediment (USEPA 1996) and has been applied in a variety of settings including rivers, near-shore areas, and estuaries (USEPA 2005).

Rechannelization was also considered, but was not carried forward as a containment technology in Area 1 due to poor implementability. Area 1 consists primarily of a free-flowing main channel not conducive to rechannelization. Administrative concerns (e.g., attainment of land for river reconfiguration, agreement with adjacent property owners, etc.) would likely limit the applicability of this technology.

3.1.1.7 Sediment Removal

Removal was retained for combination into alternatives. Removal includes the process options of mechanical dredging, hydraulic dredging, and excavation “in the dry.” Mechanical dredging in the wet appears to be the most viable of the three process options under sediment removal based on the success of the TCRAs completed in the former Plainwell Impoundment and Plainwell No. 2 Dam Area. The design for the TCRA completed in the former Plainwell Impoundment included both mechanical dredging in the wet and excavation in the dry after installation of cofferdams and construction of a water control structure (WCS). While operation of the WCS successfully lowered water levels, excavation in the dry was not achieved because of field conditions. The design for the Plainwell No. 2 Dam Area TCRA included mechanical dredging in the wet, which was successfully implemented during construction.

Hydraulic dredging has been excluded as an option because water depths are typically too shallow to support dredging equipment barges, and because of the cost of mobilizing and relocating such equipment to address isolated areas of impact.

Mechanical dredging can be performed from shore or from barges where water depth allows. Both approaches incorporate engineering controls (e.g., silt curtains, sheet pile walls, etc.) to minimize impacts to the aquatic environment during construction. The utility of mechanical dredging would be considered in targeted locations of Area 1 based on key considerations, such as remediation area dimensions, water depth, and shoreline accessibility. This process option is implementable in constricted or confined areas, such as working adjacent to shoreline structures. Excavation in the dry may also be considered as necessary or appropriate for specific areas that could be more effectively addressed with this process option (e.g., shoreline areas that could be managed in the dry).

Both excavation options can reduce potential risks associated with exposure to PCB-containing sediment over the long term, although residual concentrations may remain post-removal and could require an attenuation period and/or placement of a cover over residuals to achieve short-term goals. Other challenges associated with effectiveness and implementation of removal include the temporary damage or destruction of benthic habitat including areas damaged or destroyed while constructing access roads and staging areas, short-term ecological exposure risks due to sediment resuspension, exposure risks to remediation workers, community impacts associated with site access and construction traffic for hauling recovered material to disposal facilities, and persistence of residuals not accessible for removal.

3.1.1.8 Treatment

Treatment was retained for combination into alternatives involving removal. Treatment includes process options for dewatering and subsequent treatment of dewatering fluids. The drained water would be collected, treated, and discharged to the river. Sediment was dewatered and dewatering fluids were treated successfully during the TCRAs.

In addition to dewatering, dredged material may be treated with amendments to chemically bind wet materials or physically segregate water from PCB-containing solids. During the TCRAs in the former Plainwell Impoundment and Plainwell No. 2 Dam Area, dry soil mixing (where possible) and solidifying agents (portland cement, cement kiln dust, or other sorbent materials) were effectively used as amendments prior to off-site transport and disposal.

3.1.1.9 Disposal

Disposal was retained for combination into alternatives involving removal. Process options considered for the disposal of dredge or excavated material include a confined disposal facility (CDF), or off-site permitted facility. Soil and sediment removed during the TCRAs were manifested for off-site disposal at Allied Waste's C&C Landfill located in Marshall, Michigan; EQ's Wayne Disposal Facility in Detroit, Michigan; or Allied Waste's Ottawa County Farms

Landfill located in Coopersville, Michigan. Disposal at an off-site permitted facility was retained as the representative process option based on the successful implementation of the TCRAs, and relative cost of building and permitting a CDF. On-site disposal was rejected based on the volume to be disposed and the impracticality of purchasing land and permitting it for this purpose.

3.1.2 Floodplain Soil Technologies Evaluation

Floodplain soil remediation technologies and process options were evaluated to reject those that were less viable and/or not applicable. The results of this screening are presented in Table 3-2. The following technologies/process options were retained to develop floodplain soil remedial alternatives:

- No Further Action
- MNR
- ICs/ECs
- Containment (capping)
- Removal of impacted soil (excavation)
- Treatment (dewatering, amendment addition)
- Disposal (on-site or off-site landfill)

The floodplain soil remediation technology screening is summarized below.

3.1.2.1 No Further Action

No Further Action was retained as required by the NCP to be used as a baseline against which other floodplain soil remedial alternatives will be evaluated. Typically, this process option is described as No Action, but because of the Plainwell TCRA actions affecting floodplain soil in Area 1 (see Section 1.3.4), it is appropriate to refer to this process option as No Further Action. While ongoing natural recovery processes drive the effectiveness of this process option in achieving RAOs, the reductions in exposure and risk achieved through ongoing natural recovery processes would not be tracked through monitoring.

3.1.2.2 Monitored Natural Recovery

MNR was retained as a GRA. MNA would involve monitoring to confirm that natural physical, chemical, and/or biological processes are attenuating PCBs in floodplain soil. PCB degradation occurs very slowly. The primary mechanism for natural attenuation of PCBs in surface sediment is anticipated to be the deposition of cleaner sediment during periodic flooding events, filtering of storm runoff from upland areas, and accumulation of vegetative debris. This deposition over time would effectively become a natural cap, which would reduce the bioavailability of PCBs in floodplain soil.

As described in the USEPA-approved Area 1 SRI Report (ARCADIS 2012a), the natural floodplains of Area 1 (that is the stretch of Area 1 upstream of the Plainwell No. 2 Dam Area) continue to be periodically inundated, though the periods of flooding are relatively short-lived. PCB mass in transport in the river has declined considerably since 1994. Consequently, ongoing depositional processes in the floodplain and biodegradation processes will likely contribute to reducing soil PCB exposure concentrations over time. The rate of natural recovery is unknown at this time because no study of MNR in floodplain soil of the Kalamazoo River has been undertaken since the removal of the former Plainwell Dam.

3.1.2.3 ICs
For this GRA, land use restrictions were retained as the representative process option for floodplain soil. Institutional controls are currently in place for floodplain and bank soil as part of the 2007 AOC for the former Plainwell Impoundment TCRA, the 2000 AOC for the King Highway Landfill OU, and the 2009 Consent Decree for the Willow Boulevard/A-Site OU. These documents specify long-term maintenance of the restored riverbanks within the former Plainwell Impoundment and long-term maintenance to prevent PCBs from entering the river in the future. No additional institutional controls would be implemented beyond the existing governmental and proprietary controls that are currently in place, for these areas. Existing floodplain development restrictions and permitting requirements governing land uses will prohibit construction activities that would disturb PCB-containing soil or cause unacceptable erosion and migration of this material.

3.1.2.4 ECs
Riverbank erosion control by armoring or vegetative cover was retained as a representative process option for this GRA. Erosion control was retained to address potential eroding banks with elevated PCB concentrations and banks/buffer areas restored during the former Plainwell Impoundment and Plainwell No. 2 Area TCRAs, if necessary. Armoring and vegetative cover were used successfully to provide erosion control and bank stabilization during completion of the TCRAs. It is possible that these options may have location-specific applications during remedy implementation; their use would be considered further during detailed design, as necessary.

3.1.2.5 In Situ Containment
Construction of a soil cover or an engineered barrier (a multilayer cap consisting of impermeable layer, sand, gravel, clay, geotextiles, and/or topsoil) was retained as a representative process option for this GRA. These containment technologies protect receptors from exposure to the PCB-impacted media below. Soil covers can be used where prevention of contact by a permeable barrier is sufficient to control exposure. Engineered barriers are employed where an impermeable cap is required to prevent migration of contaminants. In both cases, the top cover layer would be vegetated to restore habitat destroyed during cap construction. This process option would be effective and is implementable in most floodplain areas. Floodplain evaluations and state permitting would be required if final ground surface elevations are to be modified through cap or cover installation. The appropriate equipment, materials, and personnel are available.

3.1.2.6 Removal
Excavation was retained as a representative process option for this GRA. Excavation with and without backfilling was successfully implemented in bank and floodplain areas as part of the TCRAs completed in the former Plainwell Impoundment and the Plainwell No. 2 Dam Area, and would be implementable in other parts of Area 1 with conventional earthmoving equipment. Removal would be effective in reducing potential risks associated with exposure to PCB-containing floodplain soil over the long term, although some risks would be associated with implementation (e.g., the ecological habitat would be temporarily disturbed/destroyed including areas damaged or destroyed while constructing access roads and staging areas). Where a large volume of soil is excavated and requires off-site disposal, potential risks would be associated with dust generation and potential public exposure during transport. The need to provide backfill would depend on the anticipated residual PCB concentration following excavation, final surface elevation and grading requirements, and restoration requirements.

3.1.2.7 Treatment

Treatment was retained for combination into alternatives involving removal. Treatment includes process options for the dewatering floodplain soil and the addition of soil amendment. Portland cement, cement kiln dust, and other sorbent materials were used effectively as amendments prior to off-site transport and disposal during the TCRAs.

3.1.2.8 Disposal

Disposal was retained for combination into alternatives involving removal. Process options considered for the disposal of excavated material include a CDF, or off-site permitted facility. Soil and sediment removed during the TCRAs were manifested for off-site disposal at the Allied Waste's C&C Landfill in Marshall, Michigan; EQ's Wayne Disposal Facility in Detroit, Michigan; or Allied Waste's Ottawa County Farms Landfill in Coopersville, Michigan. Disposal at an off-site permitted facility was retained as the representative process option based on the successful implementation of the TCRAs, and relative cost of building and permitting a CDF. On-site disposal was rejected based on the volume to be disposed and the impracticality of purchasing land and permitting it for this purpose.

3.2 REMEDIAL ALTERNATIVES DEVELOPMENT

As required in Section 5.1.4 of the SOW, a range of remedial alternatives were assembled for media of concern using the representative process options carried through the preliminary and secondary screening steps. The remedial alternatives for Area 1 sediment and floodplain soil were developed based on Agency input, the findings of the Area 1 SRI, experience obtained through the conduct of the TCRAs in Area 1, and the technology screening process. The sediment and floodplain soil alternatives provide a range of potential cleanup approaches and options to achieve the RAOs described in Section 2.2. Once a final remedial approach has been selected, it may be modified during the design and implementation phases from the alternative descriptions below because of engineering considerations, localized site conditions, and/or new information.

For the purposes of this discussion and future evaluations conducted during the FS, sediment and floodplain soil remedial alternatives are considered independently. This simplifies the process of alternative development and evaluation due to the different physical conditions and PRGs applicable to these media. Implementation of the remedies for sediment and floodplain soil may be conducted concurrently where this would result in potential cost savings and efficiencies through reuse of common remedial components such as labor, equipment, access roads, and staging areas. Sequencing of remedial activities would be considered during remedial design of the selected sediment and floodplain soil remedies.

3.2.1 Sediment Remediation Areas

The PCB SWAC analysis (presented in Section 1.3.1.1) is an appropriate screening tool to evaluate the distribution of PCBs and identify potential remediation locations in Area 1. The SWACs provide predictions of the average exposure concentration in a specified area (i.e., reach of the river and are appropriate tools to screen and develop the remedial alternatives. The SWACs for Sections 1 through 8 and Crown Vantage are based on limited (i.e., widely-spaced) data and additional samples will be collected in the areas targeted for remediation during a remedial design phase prior to remdial action. This sampling effort will be conducted to further define the remedial area.

The results of the SWAC analysis (see Table 1-2a) show that the Section 3 (Portage Creek [RM71.65] to Mosel Avenue ~~(~~[RM70.00~~)~~]) PCB SWACs were relatively higher than the other sections ~~(see Table 1-2)~~, and it is a candidate for remedial action evaluation. The Section 3

SWACs were 2.19 mg/kg for the 0- to 6-inch interval, 4.25 mg/kg for the 6- to 12-inch interval and 18.13 mg/kg for the 12- to 24-inch interval. The SWACs for all other sections and intervals were less than 1 mg/kg with the exception of Section 8. The sediment PRG of 0.33 mg/kg for PCBs would be met by reducing the ~~SWAC from 1 or less~~SWACs to 0.33 mg/kg (sediment PRG) through removal actions and/or natural recovery processes. This expected reduction is consistent with the ~~anticipated~~ SWAC reduction ~~for~~achieved by the Portage Creek TCRA currently ~~being conducted~~completed by USEPA in 2013. Remedial activities in Portage Creek ~~are predicted to produce~~produced a post-remedial SWAC of 1.8 mg/kg, which will be further reduced over time via natural recovery processes to levels acceptable to USEPA. As noted in Section 1.3.1.1, the Section 8 SWACs were calculated using primarily pre-TCRA data and are not representative of current conditions. The current conditions in Section 8 will be further evaluated during the remedial design phase. Therefore, Section 3 is targeted for further statistical and geomorphic (physical features) evaluation to develop sediment remedial alternatives.

A geomorphic–PCB RAL analysis was performed with the objective of identifying the most likely areas within Section 3 where relatively higher concentrations of PCBs would be found. In addition to areas identified through the geomorphic-PCB analysis, remedial alternatives were developed for known hot spot areas (multiple samples showing PCB concentrations greater than 50 mg/kg) in Section 3. The geomorphic–PCB analysis was performed in accordance with the procedures agreed to by the Work Group formed by USEPA, MDEQ, and Georgia-Pacific from May to July 2013 (Work Group).

Remedial alternatives are also developed for the Crown Vantage side channel and known hot spot areas in Sections 2 and 4. The Crown Vantage side channel has SWACs of 8.2 mg/kg for the 0- to 6-inch interval, 21.2 mg/kg for the 6- to 12-inch interval, and 21.0 mg/kg for the 12 to 24-inch interval. While the SWACs for Sections 2 and 4 are less than or near 1 mg/kg, these sections have a relatively higher upper confidence limit for SWACs for some depth intervals (Table 1-~~2~~2a) and contain known hot spot areas with multiple samples showing PCB concentrations greater than 50 mg/kg. Figures 3-1, 3-2, and 3-3 provide a summary of sampling data in Sections 2, 3, and 4, respectively, with insets for the four known hot spot areas and the Crown Vantage side channel.

Removal of PCB-containing sediment would also serve to remove some other constituents detected in Area 1 sediment. Organic constituents, such as, 4-methylphenol, benzaldehyde, and bis(2-ethylhexyl)phthalate, and metals, such as aluminum, copper, and lead, were detected in Area 1 sediment. Of the three organic constituents listed, benzaldehyde appears to be collocated with PCBs in sediment such that removal or capping would provide protection to ecological receptors from exposure to PCBs and this constituent as well. The collocation of non-PCB constituents with PCBs in the sediment does not imply that they came from a similar source area or that they are related to paper mill recycling processes. Rather, their collocation is likely a result of shared fate and transport mechanisms. Aluminum, copper, lead, 4-methylphenol and bis(2-ethylhexyl)phthalate appear to be ubiquitous in Area 1 sediment such that removal or capping within a portion of Area 1 will not notably reduce overall concentrations of these constituents in Area 1 (ARCADIS 2012c).

3.2.1.1 Geomorphic-PCB RAL Analysis

The geomorphology-based RAL analysis used sediment data from Sections 2, 3, and 4 with the exception of data from the known hot spot KRT5/FF19 in Section 3 and Crown Vantage side channel in Section 4, as shown on Figures 3-2 and 3-3, respectively. Exclusion of the data from these two hot spots was based on an agreement with the Work Group because of the unique geomorphic conditions at these areas. The remaining three hot spot areas were included in the analysis.

The geomorphic analysis first identified physical features that could affect sediment deposition, and that may be useful to predict areas of PCB accumulation. The stream tubes created for the SWAC calculations were grouped and classified according to physical (geomorphic) categories so that the PCB data points within those tubes could be associated with physical features for statistical analysis. Step-out data previously excluded from the SWAC calculations in Section 1.0 of this FS were included for the geomorphic-PCB analysis per agreement with the Work Group. The geomorphic-PCB analysis was performed for sediment depth intervals of 0 to 6 inches and 6 to 24 inches. ND results in the lowest interval of a core location were removed from the evaluation to more closely represent the impacted portion of the core.

The geomorphic categories included the following:

- Transverse Location
  - Left channel
  - Right channel
  - Mid-channel
  - Backwater (stagnant water area protected from the main river current)
  - Confluence (entry point of a flowing side channel or tributary into the main river channel)
- Channel Slope
  - Low
  - Moderate
  - High
- Curve Position
  - Inside curve
  - Mid-channel in curve
  - Outside curve
  - Straight section

The channel slope categories were developed by MDEQ and were imported unmodified for this analysis (MDEQ 2013). The MDEQ-designated low, moderate, and high slope categories are as follows:

- Low ≤ 0.0234%
- Moderate from 0.0235% to 0.0569%
- High ≥ 0.0570%

Other specific channel position categories such as point bars and proximity to flow obstructions (i.e., bridge piers) were considered, but not included in the final analysis due to lack of representative data within these categories.

The initial analysis also included sediment physical and chemical characteristics (grain size, percent solids, hard/soft designations from sediment probing assessments, and TOC). These sediment categories were not used for decision-making at this time because of limited sampling sites in Sections 2, 3, and 4. Although PCB presence may be positively correlated to a category (e.g., TOC or smaller grain sizes), a sediment sample must be collected and analyzed for these parameters throughout the Area in order to be predictive. Future sampling efforts in other Areas may be designed to use these correlations in a productive and efficient manner.

Overall, the geomorphic-PCB analysis showed a positive relationship between channel confluence and higher PCB concentrations (Tables 3-3 and 3-4 and Figures 3-4 and 3-5). Although the 50th percentile for both the edges and middle of the river channel are associated with PCB concentrations less than 1 mg/kg, the analysis also indicated that the side or edges of the river channel have higher concentrations relative to those in the center of the river. The analysis did not suggest strong positive relationships between PCB concentrations and the other categories listed above. Plots and tables summarizing the geomorphic analysis for all categories are presented in Appendix F.

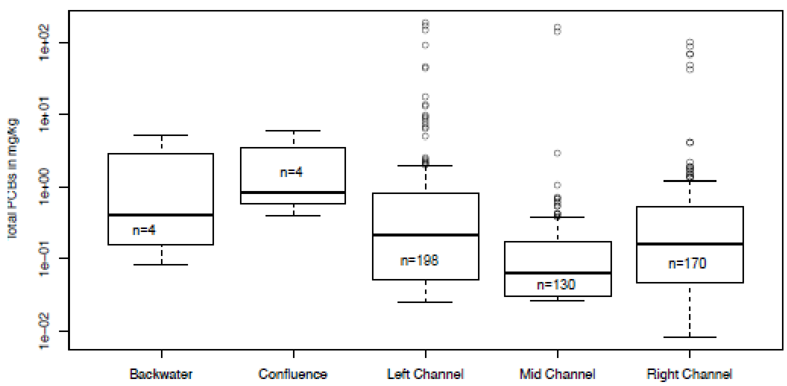
Table 3-3
Shallow (0-6″) Geomorphic-PCB Analysis Data Summary

		Quartile Range Values (mg/kg PCB)				
Data Set	**n**	**0%**	**25%**	**50%**	**75%**	**100%**
Transverse Location						
Backwater	4	0.085	0.192	0.414	1.73	5.1
Confluence	4	0.403	0.671	0.835	2.19	6.02
Left Channel	198	0.025	0.053	0.212	0.803	189
Mid Channel	130	0.026	0.030	0.063	0.172	162
Right Channel	170	0.008	0.046	0.158	0.525	101
Channel Slope						
Low	209	0.008	0.086	0.217	0.610	148
Moderate	163	0.017	0.030	0.047	0.176	68.5
High	89	0.017	0.033	0.141	0.725	189
Curve Position						
Inside Curve	101	0.008	0.095	0.264	0.940	189
Mid-channel in Curve	74	0.026	0.031	0.083	0.199	162
Outside Curve	100	0.025	0.046	0.198	0.763	101
Straight	223	0.017	0.034	0.096	0.334	17.6

Table 3-4
Deep (>6") Geomorphic-PCB Analysis Data Summary

Data Set	n	Quartile Range Values (mg/kg PCB)				
		0%	**25%**	**50%**	**75%**	**100%**
Transverse Location						
Backwater	4	0.044	0.130	0.394	2.15	6.7
Confluence	3	1.48	2.01	2.54	10.0	17.5
Left Channel	116	0.014	0.050	0.295	2.55	161
Mid Channel	65	0.015	0.042	0.133	0.530	22.4
Right Channel	85	0.021	0.037	0.210	0.451	67
Channel Slope						
Low	133	0.015	0.080	0.310	0.986	142
Moderate	64	0.021	0.032	0.115	0.385	17.7
High	52	0.014	0.034	0.130	3.56	161
Curve Position						
Inside Curve	65	0.021	0.127	0.419	4.08	161
Mid-channel in Curve	38	0.015	0.108	0.145	0.538	22.4
Outside Curve	49	0.014	0.035	0.092	0.416	52.3
Straight	113	0.026	0.034	0.180	0.540	122

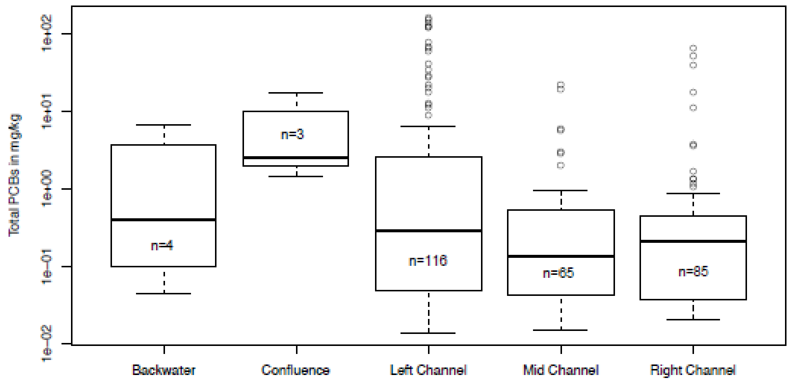
Figure 3-4
Box and Whisker* Plots of Shallow (0–6″) PCB Data by Transverse Location



n= - Represents number of sample points for a given channel location category.

*Boxes extend from lower quartile value (25%) to upper quartile value (75%). The median value is shown as a bold line inside the box. Whiskers extend 1.5 times the inter-quartile range (i.e., box height) above and below the box. Whiskers do not appear equal length due to log scale.

Figure 3-5
Box and Whisker* Plots of Deep (>6") PCB Data by Transverse Location



n= - Represents number of sample points for a given channel location.

*Boxes extend from lower quartile value (25%) to upper quartile value (75%). The median value is shown as a bold line inside the box. Whiskers extend 1.5 times the inter-quartile range (i.e., box height) above and below the box. Whiskers do not appear equal length due to log scale.

An RAL analysis was performed comparing the PCB data by geomorphic category versus PCB RAL concentration levels of 1, 2, 5, 10, and 50 mg/kg. The results of this analysis for the transverse location geomorphic categories are shown in Tables 3-5 and 3-6 for the shallow (0 inch to 6 inches) and deep (6 to 24 inches) data sets, respectively. The RAL tables for the channel slope and curve position categories are presented in Appendix F.

The probability of a confluence sample exceeding a PCB RAL of 1, 2, or 5 mg/kg was 25% for the shallow interval (0-6 inches). The shallow interval confluence samples did not exceed an RAL of 10 or 50 mg/kg. Samples from the deep interval (6-24 inches) in the confluence exceeded RALs of 1 and 2 mg/kg with a probability of 67% or greater. This probability decreased to 33% for RALs of 5 and 10 mg/kg and 0% for an RAL of 50 mg/kg. These statistics are based on only four shallow and three deep samples from two locations just downstream of the Portage Creek confluence.

Shallow and deep backwater samples have a 25% probability of exceeding RALs of 1, 2, and 5 mg/kg. No backwater sample exceeded an RAL of 10 or 25 mg/kg. The statistical significance of the backwater is low given that the 25% represents only 1 of 4 samples available in that category.

Shallow edge (right and left channel) samples have a 15% and 23% probability of exceeding an RAL of 1 mg/kg compared to the middle channel samples, which have a 3% probability of exceeding this RAL. Deeper samples show a similar pattern with 14% to 33% probability of exceeding an RAL of 1 mg/kg in the edge samples and 11% probability for the mid-channel samples. This analysis indicates that the edges of the river channel have a higher percentage of exceeding an RAL of 1 mg/kg relative to the center of the river. The probability of edge samples exceeding RALs greater than 1 mg/kg is notably less. For example, the probability of exceeding an RAL drops from 23% to 12% in the left shallow edge samples when the RAL is increased from 1 to 2 mg/kg.

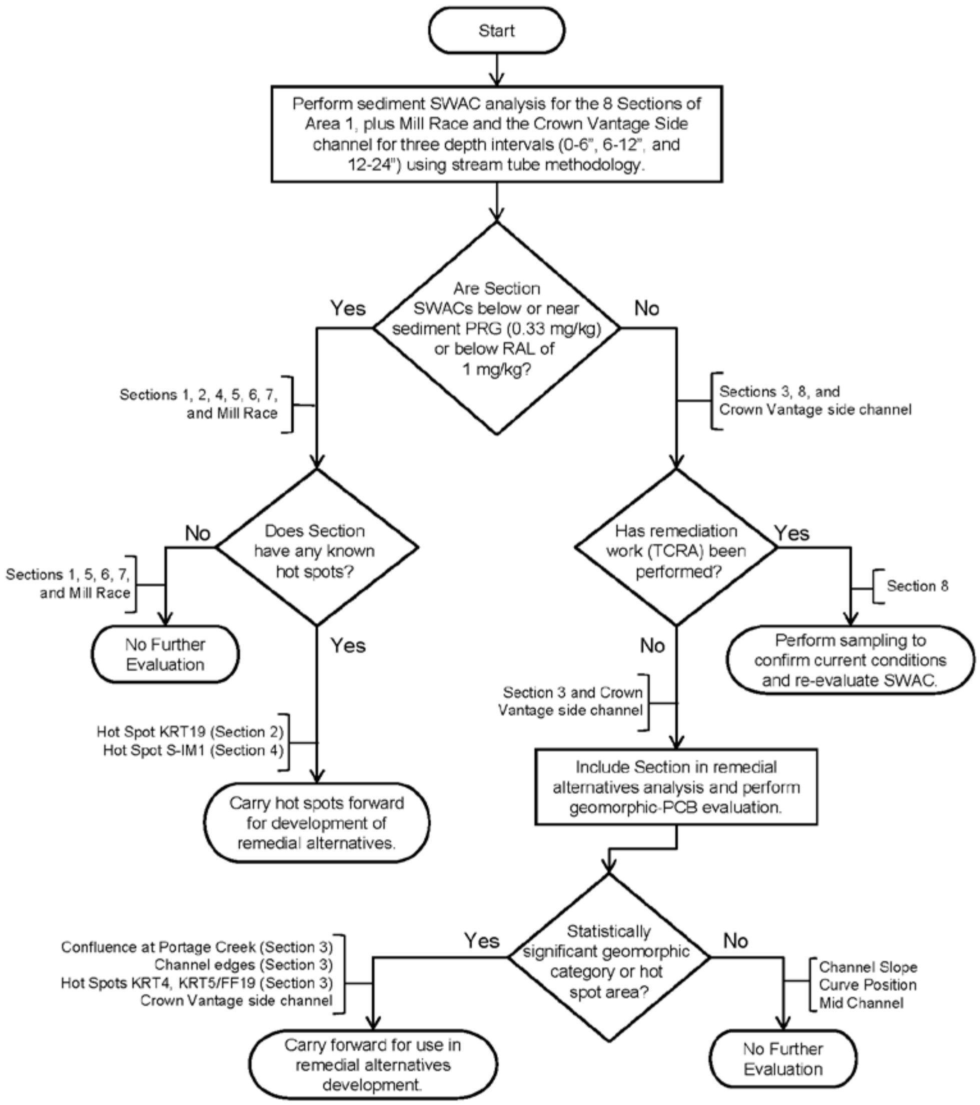
Remedial alternatives were developed based on this RAL analysis, with the hot spot areas described above. The confluence data reside in the discharge area of Portage Creek and indicate a probability of higher PCB concentrations in this area. The prediction is reasonable due to the pre-TCRA and pre-OU remediation conditions in and along Portage Creek, which was a major source of PCBs to Area 1 and specifically to the confluence area in Section 3 (RM71.65). Also, the edges of the river channel have a higher likelihood of containing higher PCB concentrations than the middle of channel, although the 50% percentile is lower than 1 mg/kg for both.

3.2.1.2 Identification of Sediment Remediation Areas

The overall process flow diagram for application of the SWAC and geomorphic-PCB analysis to identify sections and subareas requiring further evaluation of remedial alternatives is provided in Figure 3-6.

~~**Figure 3-6**~~

~~**Process Flow Diagram: Identification of Area 1 Sediment Remediation Areas**~~



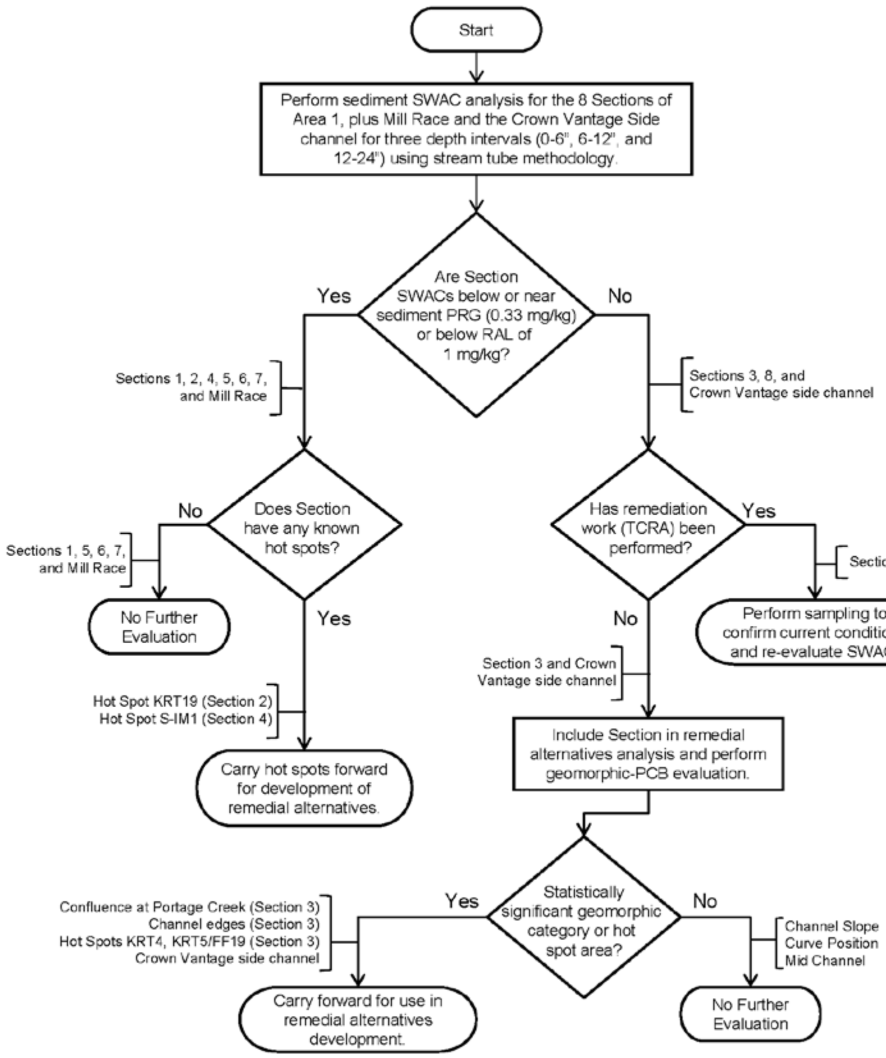
The data and geomorphic-PCB analysis indicated a potential for a PCB depositional area to exist at the confluence of Portage Creek and the Kalamazoo River in Section 3 (RM 71.65). Two known hot spots exist downstream of the confluence between RM70.5 and RM71.25 (Figure 3-2). Statistically, this portion of Section 3 would be predicted to have the highest concentrations of PCBs downstream of Portage Creek. Sampling results from this very limited area within Section 3 (about 0.75 river mile plus the Portage Creek Confluence area) appear heterogeneous and may contain other hot spot areas or may indicate a more continuous PCB remediation area. ~~This portion of Section 3 will be considered for additional sampling as part of the remedial design as described in Section 4.0 of this FS, to determine whether areas other than those identified as hot spots may require remediation.~~ Hot spots also exist in the downstream end of Section 2 and the upstream end of Section 4, bracketing Section 3. For purposes of remedial alternative development, the portion of the river spanning the hot spots in Sections 2, 3, and 4 (i.e., approximately from RM69.3 to RM 72.3) will be evaluated as a “remedial reach” that will require additional sampling as part of the remedial design (included in Section 4.0 of this FS). This remedial design sampling will be performed to evaluate whether other areas in this remedial reach (in addition to the known hot spots) will require remediation. Additional sampling during remedial design is included with all sediment remedial alternatives except MNR. Sampling will be conducted in accordance with an USEPA-approved work plan. Identification and quantification of remediation areas within the remedial reach will require concurrence by USEPA and MDEQ prior to implementation of remedial action.

The geomorphic-PCB analysis also indicated higher PCB concentration along the edges of the river channel relative to the middle of the river channel in Section 3. Therefore, sediment removal along the edges of the river channel in Section 3 was also selected for evaluation in Section 4.0 of this FS.

Figure 3-6

Process Flow Diagram: Identification of Area 1 Sediment Remediation Areas

Commented [A1]: Will add Portage creek to this figure.



Remedial alternatives will be developed for the following locations in Sections 2, 3, and 4~~, as a result of these evaluations~~.

Section 2 (Figure 3-1)

- ~~KPT19~~KPT-19 Hot Spot Area (RM72.25)
- KPT-20 Hot Spot Area (RM71.94)

Section 3 (Figure 3-2)

- ~~KRT4~~KRT-4 Hot Spot Area (RM71.10) (Figure 3-2)
- ~~KRT5~~KRT-5/FF-19 Hot Spot Area (RM70.75) (Figure 3-2)
- River channel edges (Figure 3-7)

~~Additional sampling at the Portage Creek confluence area (RM71.65) and from RM70.5 to RM71.25 (Figure 3-2)~~Section 4 (Figure 3-3)

- S-IM1 Hot Spot Area (RM69.35)
- Crown Vantage side channel (RM67.75 to RM67.90)

Outside of the hot spots listed above, one sample at transect KPT23 (sample core KPT23-6 at a depth of 12 to 20 inches), indicated a concentration of more than 50 mg/kg (Figure 3-2). Subsequent investigations to evaluate this area as a potential hot spot indicate that this sample is very isolated. The presence of high PCB concentrations in this location was not confirmed during later sampling events, as total PCB concentrations were at or below 3.7 mg/kg in all of the samples that surrounded this core interval, both horizontally and vertically. Therefore, this location is not considered a known hot spot at this time. It will be sampled again during remedial design. If sampling indicates the presence of a hot spot that should be remediated this area, it will be added to the remedial effort in accordance with USEPA and MDEQ approval.

An Area 1-wide removal alternative for sediment with PCB concentrations greater than 1 mg/kg was also evaluated in Section 4.0 to provide an upper bound on potential remedial actions. This remedial alternative would include extensive removal activities in Sections 1 through 8, the Crown Vantage side channel, and Mill Race. This alternative was developed by identifying individual stream tubes with PCB concentrations greater than 1 mg/kg in any of the three depth intervals (0 to 6 inch, 6 to 12 inch, and 12 to 24 inch), as shown in Figures 3-8a through 3-8e. A more detailed description of this alternative is provided in Section 4.0.

Pre- and post-remedial SWACs will be developed and discussed for each alternative involving active remediation in Section 4.0 of this report.

3.2.2 Sediment Remedial Alternatives

A range of alternatives was developed for sediment to achieve Area 1 RAOs. Remedial alternatives were developed by assembling combinations of the remedial technologies screened in Section 3.1.2. Bank erosion engineering controls are considered as part of the sediment remedial alternatives. Consistent with USEPA's Contaminated Sediment Remediation Guidance for Hazardous Waste Sites (USEPA 2005b), the sediment remedial alternatives include a combination of remedial options (i.e., removal in some areas and capping in others). Because capping has limited applicability in Area 1, sediment alternatives S-3, S-4, and S-5 are categorized by remedial footprint for removal rather than by remedial technology. The Area 1 sediment remedial alternatives are listed below.

- S-1: No Further Action
- S-2: MNR, ICs, and ECs
- S-3A: Removal of Hot Spot Areas and Crown Vantage Side Channel, MNR, ICs, and ECs
- S-3B: Removal of Hot Spot Areas, In-situ Capping for Crown Vantage Side Channel, MNR, ICs, and ECs
- S-4A: Removal of Hot Spot Areas, Crown Vantage Side Channel, and Section 3 River Channel Edges, MNR, ICs, and ECs
- S-4B: Removal of Hot Spot Areas and Section 3 Channel Edges, In situ Capping for Crown Vantage Side Channel, MNR, ICs, and ECs
- S-5: Area 1-Wide Removal (RAL 1), MNR, ICs, and ECs

It is assumed that all active remedial alternatives will include a long-term monitoring program and maintenance of institutional controls until long-term goals are achieved. Active remedial alternatives would also include additional sampling in Section 8 to document post-TCRA conditions and additional sampling for hot spot areas from River Mile ~~RM70.5 to RM71.25 and at RM 71.65 (Portage Creek confluence).~~RM69.3 to RM72.3. A sampling work plan will be developed and approved by USEPA prior to implementation. Concurrence by USEPA and MDEQ on the remedial footprint will also be required prior to remedial action.

The specific methods for implementation of the selected remedy will be identified during design based on engineering considerations and remediation area characteristics. Identification of the remedial area footprints will be confirmed through remedial design sampling. Construction considerations include access and preparation, erosion and sedimentation controls, material handling, and post-construction verification surveys. While details of implementation and processes are provided for evaluation purposes in this FS, the specific methods for implementation of the selected remedy will be identified during remedial design. ~~The sediment alternatives also assume that the successful completion of the Portage Creek TCRA precedes additional Area 1 remedial action.~~

3.2.3 Floodplain Soil Remediation Areas

3.2.3.1 Floodplain Soil RAL Analysis

The evaluation of each RAL began with identification of areas where surface (0- to 6-inch depth interval) soil PCB concentrations are currently greater than the specified RAL. This identification was based on the spatially interpolated surface (natural neighbor interpolation) soil PCB concentration map developed for the Area 1 TBERA (ARCADIS 2012a) for post-removal action conditions in the former Plainwell Impoundment and the Plainwell No. 2 Dam Area. An RAL of 20 mg/kg was selected based on an evaluation of the incremental risk reduction offered by successively lower candidate RAL values to achieve the selected PRG (Appendix G).

For the former Plainwell Impoundment and the Plainwell No. 2 Dam Area, the areas greater than a quarter acre with soil concentrations exceeding 20 mg/kg were delineated. The PCB concentration in each polygon above this concentration was then replaced with a concentration of 0.078 mg/kg, which represents the assumed PCB concentration of clean backfill placed after excavation. The appropriately sized moving window (1 or 2 acres based on the ecological receptor) was then ~~run~~passed over the altered surface to calculate post-remediation exposure point concentrations (ARCADIS 2012b, Appendix A).

A range of RALs was considered to compare incremental risk reduction to the current post-TCRA conditions. Candidate PCB RALs of 0.5, 5, 10, 15, 20, and 25 mg/kg for floodplain soil were evaluated within the formerly inundated areas in the former Plainwell Impoundment and/or Plainwell No. 2 Dam Area (ARCADIS 2012b). A summary of the RAL analysis previously compiled for Area 1 floodplain soil is presented in Appendix G. Outside the two TCRA areas, the detailed RAL analysis was not conducted for natural floodplains because of the low soil PCB concentrations observed.

The protectiveness of each candidate RAL scenario was considered based on the protectiveness to potential receptors and the scale of the possible remedy. Table G-3 in Appendix G summarizes the area, volumes, and protectiveness of each RAL scenario for the various ecological receptors for which possible risk was identified in the Area 1 TBERA (ARCADIS 2012d) and the Site-Wide BERA (CDM 2003).

The following RALs were considered by area as follows:

- An RAL of 0.5 mg/kg was considered for all of Area 1. A home range analysis was not performed for this RAL as resulting EPCs throughout the Site would be protective of the lowest RBC for ecological species following implementation (100% of home ranges protected).
- Home range analysis for RALs of 5, 10, 15, 20, and 25 mg/kg was performed for the former Plainwell Impoundment. The 0.5 mg/kg RAL was also considered, as described above.
- Home range analysis for only RALs of 5 mg/kg and 10 mg/kg was performed for the Plainwell No. 2 Dam Area because residual (post-TCRA) soil PCB concentrations are already below 15 mg/kg in the Plainwell No. 2 Dam Area. The 0.5 mg/kg RAL was also considered, as described above.

An Area 1-wide RAL of 0.5 mg/kg is proposed to provide an upper bound on potential remedial actions protective of ecological receptors. Remediation to this level would result in 100% of home ranges for birds and mammals being protected based on RBCs in the Plainwell No. 2 Dam Area and the former Plainwell Impoundment areas, including the most conservative values, regardless of the uncertainty in their application.

A second soil PCB RAL of 20 mg/kg is applied to the former Plainwell Impoundment (TCRA). A soil PCB RAL of 20 mg/kg is recommended; USEPA, MDEQ and GP have agreed that 20 mg/kg is an appropriate RAL value for constructing a range of alternatives for soils to be evaluated in the FS. An RAL of 20 mg/kg is proposed for floodplain soil based on assessment of the incremental risk reduction, protecting 95% to 100% of the receptors (shrew, wren, and robin under the dietary model) and the incremental area and soil volume associated with each value. The RAL analysis for the former Plainwell Impoundment yielded the following results:

- Current conditions in the former Plainwell Impoundment are protective of 82% of the possible 1-acre shrew home ranges (i.e., concentrations are less than the selected floodplain surface soil PRG of 11 mg/kg in 82% of the possible 1-acre shrew home ranges).
- Remediating residual soils with PCB concentrations greater than 20 mg/kg in the former Plainwell Impoundment would result in 95% of the possible 1-acre shrew home ranges

having soil PCB concentrations below the selected floodplain surface soil PRG of 11 mg/kg.

- Current conditions in the former Plainwell Impoundment are protective of approximately 96% to 99% of possible high sensitivity avian 2-acre home ranges based on the dietary RBCs of 14 mg/kg for vermivorous birds and 17 mg/kg for insectivorous birds, respectively, derived from the Area 1 TBERA.
- Implementation of an RAL of 20 mg/kg would result in protectiveness of 100% of possible home ranges for high sensitivity avian species in the former Plainwell Impoundment based on the dietary exposure approach. Protectiveness of birds based on RBCs for egg-based approaches is discussed in Section 2.4.7. RBCs calculated based on egg-based approaches have a higher degree of uncertainty than the dietary approaches. Therefore, there is more certainty in the RAL analyses based on dietary RBCs.

The available data representative of potential residential exposure in the natural floodplains (i.e., outside the two TRCA areas, near-channel OUs, former mill properties, and closed landfill areas) ~~indicate that the natural floodplain conditions are typically below the selected 11 mg/kg PRG for PCBs.~~were evaluated and are presented below.

3.2.3.2 Floodplain Soil Residential Exposure Analysis

To date, a residential sampling program has not been performed in Area 1. The purpose of this evaluation is to use available floodplain soil data to estimate the risk to residential receptors in Area 1 and identify potential residential properties for future sampling during remedial design. Available surface soil samples (0-6 inch) from the 100-year floodplain along the Area 1 River in Kalamazoo County (Figures 3-9a through 3-9d) and along properties adjacent to the Area 1 River in Allegan County (Figure 3-9e) were considered in this analysis. The 100-year floodplain was designated in the available Kalamazoo County GIS files but not in the Allegan County GIS files.

The available floodplain data are relatively limited in Area 1 outside the former Plainwell Impoundment and Plainwell No. 2 Dam areas, which were remediated as part of the TCRA activities and represent a different historical hydrologic environment. The Plainwell Impoundment area was a depositional impoundment and the Plainwell No 2 Dam area is more frequently inundated due to the presence of flow diversion structures, compared to other portions of Area 1. Conditions in these locations would not be representative of residential properties along the remaining 20 miles of Area 1 or along Portage Creek.

The floodplain data currently available in the Site and MDEQ databases were compiled, plotted in GIS, and screened to remove:

- Field duplicates
- Duplicate samples between databases (i.e., samples with the same location ID, date, and result in both databases)
- Non-floodplain soil samples (e.g., samples flagged, coded, or described as “sediment,” “residual”, etc.)
- Samples collected from intervals with a start depth greater than 6 inches
- Samples from other OUs, previously excavated areas, and former potential source areas adjacent to the river (e.g., on former mill site properties and closed landfills)

- Samples from the areas where TCRAs were performed (i.e., in the former impoundment of the Plainwell Dam and frequently inundated area of the Plainwell No. 2 Dam area)

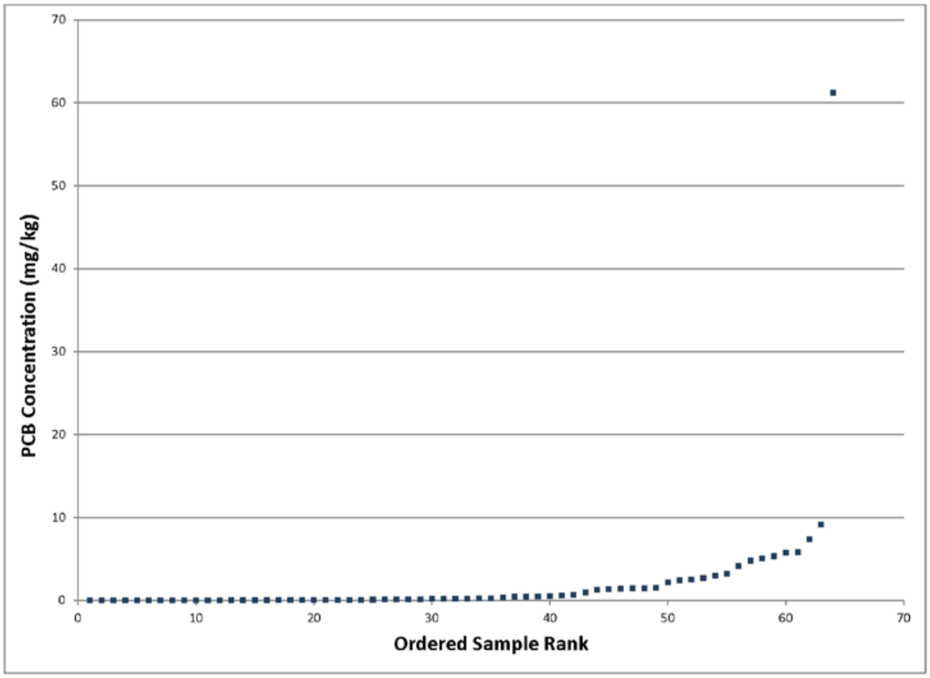
The final data set after screening contained 64 sample points from the 0- to 6-inch interval of discrete sample cores representing floodplain areas typical of the depositional environment and residential (non-industrial) property along the river. None of the data points represent full residential exposure units, which would comprise an entire backyard. Therefore, the applicability of these samples is limited such that the interpretation of the data is a general indication of potential conservative residential exposure. Representative samples for residential exposure will be collected as part of the remedial design to better quantify this risk.

Property plat data was procured from Kalamazoo and Allegan Counties in Michigan and imported into GIS to identify the locations and density of residential properties along the river in Area 1. The residential property designation was taken directly from the counties' database. The county property plats are plotted on Figures 3-9a through 3-9e. Shading is used to indicate the properties zoned/classified as residential. These figures also show the floodplain soil data points used in this evaluation. Many of the data points appear to be located in the riverbank, or possibly, at the top of the bank. These potential bank samples were retained in this evaluation although they may not be representative of residential exposure concentrations.

Results and Recommendations

The screened floodplain soil data set was exported to ProUCL to compute the 95% Chebyshev UCL. The 95% UCL for the data set is 6.45 mg/kg. A plot of the ranked dataset is shown on Figure 3-10. See Appendix E for the full data set (Table E-4) and ProUCL output (Table E-5). Only 3 of the 64 data points (5%) exceed the computed UCL, and the highest value (61.2 mg/kg) exceeds the next highest value (9.16 mg/kg) by a factor of nearly 7. The maximum value of 61.2 mg/kg was detected in what appears to be a riverbank sample located at approximately RM64.3 in river Section 5 (Figure 3-9d).

Figure 3-10
Ranked Plot of Area 1 PCB Floodplain Data
Surrogates for Estimating Residential Exposure



The calculated UCL appears to be ~~very~~ conservative, because excluding the maximum value produces a UCL of 1.72 mg/kg (Table E-6). With or without the maximum value, the calculated UCLs are within or below the 2.5 to 15 mg/kg range calculated to be protective of human health for residential receptors in the BHHRA (CDM 2003a) (see Figure 2-2). These concentrations are also within the acceptable range of 1 to 10 mg/kg for total PCBs in residential areas under TSCA. The UCL of 1.72 mg/kg PCBs, which excludes the river bank sample, is below the MDEQ threshold value of 4 mg/kg for residential receptors. The evaluation of existing floodplain data indicates that Area 1 floodplain soil concentrations do not pose unacceptable risk to human health or the environment. However, this statement will be confirmed by additional residential sampling during the remedial design.

The recommendations for future confirmation sampling include the following.

- Perform reconnaissance with USEPA/MDEQ to select representative residential properties for sampling and confirm that the property is residential.
- Obtain access agreements from property owners.
- Perform incremental sampling within residential exposure units (e.g., backyards adjacent to the river) during the remedial design phase.

3.2.3.3 Floodplain Soil Remediation Areas

Results of the moving-window home range analysis indicated that implementing remediation for an RAL of 20 mg/kg results in ~~98~~95% of ~~the~~ possible 1-acre home ranges ~~(~~for vermivorous mammals (based on the total PCB exposure model for the shrew) having concentrations below the selected PRG of 11 mg/kg~~. The 98% is a composite percentage of achieving 95%~~ in the former Plainwell Impoundment area~~ and 100%~~, as presented in ~~the Plainwell Dan No. 2 area. Current soil concentrations in Plainwell Dam No. 2 do not exceed 20 mg/kg.~~Appendix G. An RAL of 20 mg/kg PCBs is also assumed to be protective of avian receptors as it represents a balance between risk and uncertainty associated with the various methodologies and assumptions used in the TBERA to calculate risk to avian receptors. An RAL of 20 mg/kg would ~~also~~ result in 100% of possible 2-acre home ranges ~~(~~for high sensitivity insectivorous and vermivorous birds~~) being below the 11 mg/kg PRG~~ (based on the dietary exposure ~~model~~models for the wren and American robin ~~(ARCADIS 2012b) (Appendix G). The~~) being below the respective dietary RBCs from the Area 1 TBERA (17 mg/kg and 14 mg/kg, respectively) in the former Plainwell Impoundment. The former Plainwell Impoundment floodplain soil area exceeding an RAL of 20 mg/kg comprises approximately 7 acres ~~in the former Plainwell Impoundment~~ (Figure 3-11~~).~~) and 15,000 cy of floodplain soil. Current PCB soil concentrations in Plainwell No. 2 Dam Area do not exceed 20 mg/kg.

An Area 1-wide removal alternative for floodplain soil with PCB concentrations greater than 0.5 mg/kg was also evaluated to provide an upper bound on potential remedial actions. This remedial alternative would include extensive removal activities along the river spanning Sections 2 through 8 (approximately 17 miles). Section 1 was not included as it is upstream of the paper-mill related PCB inputs to Area 1. For the former Plainwell Impoundment and Plainwell No. 2 Dam areas, the excavation areas are based on the 0.5 mg/kg RAL analysis (Appendix G). For the remainder of Sections 2 through 8, it was assumed that removal would be performed to a depth of 1 foot in a 200-foot-wide continuous band along the banks on each side of the river, as indicated on Figure 3-12. A more detailed description and evaluation of this alternative is provided in Section 5.0.

3.2.4 Floodplain Soil Remedial Alternatives

Remedial alternatives were developed for floodplain soil to provide a range of alternatives to achieve Area 1 RAOs. Remedial alternatives were developed by assembling combinations of the remedial technologies screened in Section 3.1.2. The Area 1 floodplain soil (FPS) remedial alternatives categorized by remedial technology are listed below.

- FPS-1: No Further Action
- FPS-2: MNR, ICs, and ECs
- FPS-3: Capping (RAL 20) ICs, and ECs
- FPS-4A: Removal (RAL 20), ICs, and ECs
- FPS-4B: Removal (RAL 0.5), ICs, and ECs

The above alternatives would address both PCBs and constituents that are collocated within a remedial area. Metals such as chromium, copper and lead, as well as organic compounds such as aldrin, and endrin aldehyde tend to be collocated with PCB in soil in Area 1 so that a cap or removal action would provide protection to ecological receptors from exposure to PCBs and these constituents as well. The collocation of non-PCB constituents with PCBs in the floodplain soil does not imply that they came from a similar source area or that they are related to paper mill recycling processes. Rather, their collocation is likely a result of shared fate and transport mechanisms. Other constituents such as benzaldehyde appear to be ubiquitous in Area 1 soil such that capping within a portion of Area 1 will not notably reduce overall ecological risk associated with exposure to such non-collocated constituents (ARCADIS 2012c).

Construction considerations are similar to those for the sediment alternatives and include access and preparation, erosion and sedimentation controls, material handling, and post-construction verification surveys. While details of implementation and processes are provided in this description for evaluation purposes, the specific methods for implementation of the selected remedy would be identified during remedial design. The floodplain alternatives also assume that the Portage Creek TCRA is successfully completed prior to additional Area 1 floodplain remedial action. USEPA reported that removal activities for Portage Creek should be completed in October 2013, but work could extend into 2014 depending on weather conditions.

3.3 EVALUATION CRITERIA

Each of the sediment and floodplain soil alternatives identified above will be evaluated in detail individually and also comparatively against the nine criteria established in 40 CFR §300.430(e)(9)(iii) in Sections 4.0 and 5.0. These nine evaluation criteria are divided into the following three categories: threshold criteria (each alternative must meet these criteria), balancing criteria (basis for alternative selection), and modifying criteria (applied following the proposed plan). The specific evaluation criteria that fall under each of these categories are listed below.

Threshold

- Overall protection of human health and the environment
- Compliance with ARARs

Balancing

- Short-term effectiveness
- Long-term effectiveness
- Reduction of toxicity, mobility, and volume (TMV) through treatment
- Implementability
- Cost

Modifying

- State acceptance
- Community acceptance

The remedial alternatives will be evaluated for the first seven criteria and then compared with one another to identify their respective strengths and weaknesses. Two criteria, State and community acceptance, will not be evaluated because they will be based on comments received and addressed in the Proposed Plan Public Meeting and Record of Decision (ROD) following the public review period.

4.0 DETAILED ANALYSIS OF SEDIMENT ALTERNATIVES

A detailed evaluation of the seven remedial alternatives for Area 1 sediment has been performed based on the CERCLA evaluation criteria. A description of each alternative is presented, followed by a summary of the evaluation of the seven CERCLA Threshold and Balancing Criteria. The two Modifying Criteria, State and community acceptance, are not evaluated in the Area 1 FS; USEPA will address the Modifying Criteria based on comments received during the comment period for the proposed remedial action plan.

4.1 ALTERNATIVE S-1: NO FURTHER ACTION

4.1.1 S-1 Description

The No Further Action remedial alternative (S-1) would rely on natural recovery processes following the TCRAs and OU source control activities previously completed in and adjacent to Area 1 (summarized in Section 1.3.4). No active remediation or monitoring would be included under this alternative. Changes to sediment conditions or PCB concentrations in the water column and fish tissue resulting from natural recovery processes would not be formally evaluated. No Further Action is considered as a baseline against which other Area 1 sediment alternatives are compared as required by the NCP [40 CFR 300.430(e)(6)].

4.1.2 S-1 Alternative Evaluation

4.1.2.1 Overall Protection of Human Health and the Environment

The No Further Action alternative would not improve, reduce, or control risk to human health or ecological receptors beyond that initiated by the remedial work completed to date and the Portage Creek removal action being implemented by USEPA. Monitoring of further natural recovery would not be performed under the ROD. This alternative may not address the RAOs and may require a timeframe to achieve fish tissue goals beyond that evaluated in this FS.

4.1.2.2 Compliance with ARARs

Potential federal and State ARARs applicable to Area 1 sediment are addressed in Section 2.3 and listed in Tables 2-1 through 2-3. Alternative S-1 may eventually meet most ARARs through natural recovery; however, the timeframe may be longer than that evaluated in this FS and documentation of recovery would not be available.

4.1.2.3 Long-Term Effectiveness

Alternative S-1 does not provide for tracking or confirmation of future achievement of RAOs, under a ROD and, therefore, effectiveness would not be demonstrated or documented.

4.1.2.4 Short-Term Effectiveness

Alternative S-1 would not have any immediate short-term impact.

4.1.2.5 Reduction in TMV through Treatment

This alternative does not involve treatment.

4.1.2.6 Implementability

No measures are implemented under this alternative.

4.1.2.7 Cost

Alternative S-1 has no capital or maintenance cost.

4.2 ALTERNATIVE S-2: MNR, ICs, AND ECs

4.2.1 S-2 Description

This alternative applies MNR and ICs/ECs and relies on natural recovery processes following the active remediation activities conducted as part of the TCRAs and OU source control activities previously completed in and adjacent to Area 1 (see Section 1.3.4). Further improvements beyond current conditions in Area 1 sediment and progress toward RAOs would rely on ongoing natural recovery processes. These processes include deposition of cleaner sediment from the watershed, mixing of surface and cleaner sediment, and, possibly, biodegradation. Existing ICs/ECs (fish consumption advisories and warning signs) would continue under S-2.

MNR would include implementation of a LTM program to confirm the ongoing effects of natural processes and document the continued declines in PCB concentrations in various media, resulting in reductions in risk and ecological exposures. It is anticipated that the monitoring program would be in addition to the current MDEQ program that includes fish and water column monitoring. Monitoring would continue over the FS evaluation period of 30 years for alternative S-2 (and other alternatives that include MNR). The final components of the LTM program would be defined as part of the ROD; however, for developing cost estimates it is assumed that the LTM program would include the following activities. Detailed costing assumptions are presented in Appendix H.

- Fish monitoring annually for the first 5 years, then once every 5 years for the remainder of the LTM period. Fish samples would be collected within locations spanning Area 1 and the reference/background areas. The actual sampling locations will be specified in the ROD or during the remedial design process. Smallmouth bass and carp would be collected at each sampling location. Adult carp and both adult (fillet) and YOY (whole body) smallmouth bass would be collected and analyzed for total PCBs and lipid content.
- Surface water quality monitoring would occur annually for the first five years then once every five years for the remainder of the LTM period to support periodic review by USEPA, which typically occur every five years. Samples would be collected representing each of the eight Sections of Area 1. Water samples would be analyzed for total PCBs.
- Sediment samples would also be collected to support the 5-year reviews by USEPA by monitoring ongoing recovery conditions and natural attenuation in selected portions of Area 1. The sampling areas will be selected following completion of remedial action.
- Visual inspections of riverbank erosion would occur annually for the first five years then once every five years for the remainder of the LTM period, plus additional inspections after major storm/flooding events, as necessary.

Commented [A2]: Remedial cost to be increased. For additional sampling.

Site-specific fish consumption advisories established and publicized by the State of Michigan would continue as a component of S-2 to manage risks posed to anglers and their families by consumption of PCB-containing fish. ~~This institutional control is~~These advisories are already in place for Area 1 (MDCH 2011~~). These ICs~~), and the advisory for each fish type would remain in ~~place~~effect until fish tissue PCB concentrations achieve RAOs~~, and~~ in that fish. The advisories would be reviewed and verified annually as a component of the site institutional controls. Fish advisories, alone, would not be an appropriate remedial alternative.

4.2.2 S-2 Alternative Evaluation

4.2.2.1 Overall Protection of Human Health and the Environment

Completed and ongoing source control efforts have resulted in the control or elimination of the most significant sources of PCBs to Area 1. Natural recovery of the river subsequent to these remedial activities and declining PCB levels in fish and the water column would be documented through LTM. Fish consumption advisories for each fish type will remain in place until the RAOs are achieved in that fish.

Future fish tissue concentrations under this alternative have been projected based on the historical fish tissue trends observed to date (Section 1.3.1.3 and Appendix B). Current rates of decline range from 0 to 7.7% per year depending on the fish species, as listed in Table 1-4. These rates represent a variety of conditions occurring simultaneously and include, but are not limited to, removal/source control activities, resuspension during removals and high flood events, deposition of cleaner sediment over impacted sediment, dilution with incoming sediment, ~~changes in PCB load to the river, and natural recovery. Table 4-1 lists projections of the time to achieve fish tissue PRGs for MNR with future declines set at 2% per year. The 2% per year rate reduction was selected as a conservative rate to represent MNR. The rate of reduction due solely to MNR in this data set cannot be separated from the other processes, and the actual MNR may be greater or less than 2%.~~and changes in PCB load to the river (point sources, surface runoff, aerial deposition, etc,).

~~Time projections are provided for the urban reach (Sections 3 and 4) and dam reach (Sections 5, 6, 7, and 8) for each fish tissue sample type (smallmouth bass fillets, whole-body smallmouth bass, and common carp fillets). The target smallmouth bass fillet concentration is 0.23 mg/kg based on the high-end sports angler RBC and the upstream reference area concentration. The target whole-body smallmouth bass concentration is 0.6 mg/kg based on mink consumption (see Figure 2-1). The target common carp fillet concentration is 0.29 mg/kg based on the upstream reference area concentration. These values do not take lipid content into consideration, and are applied based on intake rates for the high-end sport angler or background fish tissue concentrations. Actual exposure risk may vary depending on the lipid content for a specific fish type and the season of catch. Time projections are measured from ROD issuance.~~

~~Under MNR, smallmouth bass fillet concentrations are projected to meet the PRG in about 3 years in the urban areas and in about 20 years in the dam areas. Smallmouth bass whole-body concentrations are projected to meet the PRG in the urban areas in about 7 years, and already meet the PRG in the dam areas. Common carp fillets are projected to meet the PRGs in the urban and dam areas in 46 and 42 years, respectively (Table 4-1).~~

~~Upper and lower bounds on fish tissue projections were calculated for MNR assuming 0% and 7.7% (maximum statistically significant observed trend) rates of decline, respectively. These calculations are presented in Appendix I. At the upper bound (using a 0% decline), fish tissue concentrations do not change and PRGs would not be met by MNR (Table I-1). At the lower bound (using 7.7% decline), all three fish tissue types in both urban and dam areas would meet PRGs within 12 years (Table I-2).~~

~~The sediment SWAC in Sections 1, 5 and Mill Race is below the PRG (0.33 mg/kg) at all depth intervals (0-6, 6-12, and 12-24 inches), and the overall SWAC (0-24 inches) is at or near the PRG in Sections 2 and 4. SWAC estimates exceed 1 mg/kg in Sections 3 and 8 and the Crown Vantage side channel. The current (post-TCRA) concentrations in Section 8 are not considered representative of current conditions and would be re-evaluated as part of remedial design~~

~~sampling. Following the removal of most PCB inputs to Area 1 through the TCRAs and other OU actions, observed fish tissue trends indicate that natural recovery processes are occurring and implies that surface sediment concentrations are declining. Time to reach overall sediment goals in Area 1 will therefore be faster than the overall fish tissue recovery periods listed above because only Section 3 (1.7 miles) and Crown Vantage (0.20 mile) of the 22 miles in Area 1 are expected to be above a PRG of 0.33 or RAL of 1 mg/kg.~~

A range of fish tissue concentration recovery rates expressed as average annual percent declines (AAPD) were established for each fish tissue type (Table 1-4). Regression equations for the trends in historical fish tissue data were statistically tested for significance, and those significantly different than zero ($p < 0.05$) were used to project the time to meet the fish tissue goals listed under RAO1. If the available regression equations did not include a p-value < 0.05, an equation with a p-value approaching 0.05 was used.

Fish tissue historical trend regressions and future projections were calculated for two river designations in Area 1. These designations were used to separate the fish tissue data into two subsets, those identified as being in urban areas and those identified as being in dam areas. The designation “Urban Area” represents the free-flowing portion of the Kalamazoo starting in the urban area near Portage Creek. The designation “Dams Area” represents the historically quiescent portion of the Kalamazoo River at the downstream end of Area 1 starting upstream of the Plainwell No. 2 Dam area. A description of the river miles and ABSAs used to represent the Urban and Dam Areas are provided in Appendix I.

Many variables affect the estimated rates of decline for MNR and other remedial alternatives. Variation among sample data sets, limits to the analytical methods, and heterogeneity among fish and their exposure are just a few. Therefore, time projections to reach various fish tissue goals as stated in RAO1 are also expected to contain variability. A time projection based on the mid approximation was calculated by using the mid-range percent decline that was statistically significant. In addition, a 95 percent confidence interval around this mid range was calculated to demonstrate the potential variability in time projections. The reporting of upper and lower bounds on the time projection to meet the fish tissues goals is appropriate for MNR and each of the sediment remedial alternatives presented herein.

The percent decline for MNR fish tissue projections were selected as follows (the percentages for each fish type and river designation are presented in Table 4-0):

- Upper Bound: the lower confidence bound of the regression equation with the lowest AAPD was selected to represent the upper bound (slowest) rate of decline (0% for all three fish tissue types).
- Mid-range: the regression equation that resulted in the median AAPD was selected to represent the mid-range decline. If only two significant regression equations were available, the lower of the AAPDs was selected to calculate a conservative projection. (See Table 4-0 for specific rates of decline for each fish.)
- Lower Bound: the upper confidence bound of the regression equation with the highest AAPD was selected to represent the lower bound (fastest) rate of decline. (See Table 4-0 for specific rates of decline for each fish.)

These rates are cumulative such that each year the rate is applied to increasingly lower total PCB concentrations in fish tissue and produces a curve with a slope that decreases over time.

Table 4-1a through 4-1c list projections of the time (mid, lower, and upper bounds) to achieve fish tissue goals for the three fish tissue types (SMB fillets, SMB YOY whole body, and common carp fillets) for each remedial alternative. Details of the fish projection methodology with tabulations of the calculation inputs and results are presented in Appendix I.

Time projections to meet fish tissue goals under MNR (Alternative S-2) are measured from ROD issuance as the start of MNR implementation. Under MNR, fish tissue concentrations throughout Area 1 (both urban and dams areas) are projected to meet the 1 x 10^{-5} cancer risk fish tissue goal for protection of human health (0.042 mg/kg) within a mid approximatin of 87 years for smallmouth bass and 192 years for common carp. Whole-body YOY smallmouth bass are projected to meet the ecological risk goal (0.6 mg/kg for mink) in Area 1 within 7 years. The mid approximation for times to reach other risk-based goals, as listed in Tables 4-1a through 4-1c, are shorter than those stated above. Fish projections with the upper and lower bounds for each fish type for S-2 are provided in Figures 4-1a through 4-1f.

Observations made during a June 2013 visual inspection survey indicate that bank erosion is ~~minor and~~ localized to short stretches where development encroaches on the river in Area 1 (see Section 1.3.2 and Appendix C). In addition, the TCRAs have removed PCB impacted media and protected most riverbanks in areas of historical PCB deposition. Therefore, bank erosion in Area 1 is not significantly contributing to downstream PCB transport. MNR would achieve RAO 4 by continued monitoring and maintenance of the restored banks in the TCRA areas and monitoring for erosion of unremediated PCB deposits in Sections 2, 3, and 4 and the Crown Vantage side channel.

This alternative would include the installation of additional ECs for erosion control, with monitoring and maintenance over the 30-year evaluation period.

4.2.2.2 Compliance with ARARs

ARARs are discussed in Section 2.3 and listed in Tables 2-1 through 2-3. A waiver for the TSCA ARARs would be required to allow PCB concentrations greater than 50 mg/kg to remain in place and to allow PCB concentrations less than 50 mg/kg to remain in place without deed/access restrictions.

Technical impracticability waivers would be required for the Michigan NREPA water quality ARARs due to low-level continuing sources to the river that may sustain levels of PCBs in the water column (e.g., from the atmosphere, upstream areas, and urbanized areas of the watershed, etc.) and the inability to detect such low PCB concentrations, because current typical detection limits for surface water are 1.0 to 0.2 ng/L, or 8 to 77 times higher than the current Michigan water quality standards for protection of wildlife and human health.

A mid appximation of time to comply with human health ~~and ecological exposure~~(1 x 10^{-5} risk ~~targets~~) target in fish under MNR (alternative S-2) is estimated to be ~~20~~87 years for smallmouth bass and ~~46~~192 years for common carp (Table 4-1). Upper and lower bounds to this time estimate are discussed in Section 4.2.2.1, above and shown on Figures 4-1a through 4-1f. ~~Time to reach overall sediment goals (chemical-specific ARARs) in Area 1 is expected to be faster than the overall fish tissue recovery periods, given that the sediment concentrations in much of Area 1 are already below or near the PRGs, as noted above.~~

4.2.2.3 Long-Term Effectiveness

Completed and ongoing source control efforts in Area 1 and adjacent OUs have controlled the most significant sources of PCBs to Area 1, promoting the long-term natural recovery of the river and corresponding PCB levels in fish and the water column. The decreasing PCB concentrations in Area 1 fish and surface water (Sections 1.3.1.3 and 1.3.1.4) are anticipated to continue in response to these actions and ongoing natural recovery processes. Area 1 sediment PCB SWACs are also anticipated to continue to decline over time due to these processes. The SWAC estimates in Table 1-2 provide evidence of MNR because they show much lower concentrations of PCBs in the surficial (upper 6 inches) sediment compared to deeper sediment intervals. For example, the upper interval SWAC for Section 3 is 2.19 mg/kg, while the lower intervals are 4.25 and 18.13 mg/kg (Table 1-2). The lower concentrations of PCBs in the upper interval represent net ongoing recovery processes. Low-level continuing sources of PCBs from the atmosphere, upstream areas, urbanized areas of the watershed, and unremediated Area 1 sediment and floodplain soil would limit the lowest achievable levels of PCBs in fish, surface water, and sediment under S-2.

Because higher-concentration, PCB-containing sediment would remain in the river under the MNR alternative, the potential for sediment erosion and migration is relevant in the evaluation of long-term effectiveness and permanence. Sediment erosion, mixing, bioturbation, etc., would potentially result in movement of PCBs from buried intervals to the surface where they become bioavailable and would interact with the water column. However, these same processes also work to reduce overall sediment concentrations, as cleaner sediment deposits would continue to accumulate and produce lower SWACs in the surficial sediment over time.

Overall human health and ecological exposures are driven by fish tissue concentrations. Some fish tissue goals have already been met (i.e., smallmouth bass whole body in the Dams area), and projections indicate that fish tissue targets not yet met can be achieved by MNR in ~~20~~87 years for smallmouth bass and ~~46~~192 years for common carp as a mid approximation of time (Table 4-~~1~~1a).

4.2.2.4 Short-Term Effectiveness

MNR would not have any short-term impact.

4.2.2.5 Reduction in TMV through Treatment

This alternative does not involve treatment.

4.2.2.6 Implementability

Long-term monitoring and inspections would be implemented. ICs and ECs for erosion control are currently in place at the TCRA areas and would continue to be inspected and maintained.

4.2.2.7 Cost

The S-2 cost estimate is presented in Table 4-2. A present worth analysis was performed using a discount rate of 7% in accordance with USEPA guidance (USEPA 1988a). A list of cost assumptions and unit rates are provided in Appendix H.

Alterative S-2	Present Worth	$1,200,000
	Total Cost	$2,200,000

Commented [A3]: Costs to be updated to include sediment sampling as part of LTM.

4.3 ALTERNATIVE S-3A: REMOVAL OF HOT SPOT AREAS AND CROWN VANTAGE SIDE CHANNEL, MNR, ICs, AND ECs

4.3.1 S-3A Description

Alternative S-3A includes the removal of impacted sediment in ~~four~~at least five hot spot areas ~~in Sections 2, 3, and 4 (KPT19, KRT4, and KRT5/FF-19, and S-IM1)~~ and the Crown Vantage side channel ~~(Figures 3-1 through 3-3)~~,, with MNR, ICs and ECs throughout Area 1. The five identified hot spots (KPT-19, KPT-20, KRT-4, and KRT-5/FF-19, and S-IM1) are located within a stretch of Area 1 spanning from RM69.3 to RM72.3 that is designated the “remedial reach.” The remedial reach includes Section 3 and the adjacent upstream and downstream portions of Sections 2 and 4, respectively (Figures 3-1 through 3-3). Additional sampling of the remediation reach would be performed as part of the remedial design phase to further delineate the removal boundaries around the known hot spots, and to identify other locations for remediation within the remedial reach. Two additional, currently unknown hot spots are included in the cost evaluation in the anticipation of identifying additional hot spot areas during the remedial design. Sampling would be conducted in accordance with a USEPA-approved work plan. Identification and quantification of remediation areas within the remedial reach would require concurrence by USEPA and MDEQ prior to implementation of remedial action.

The anticipated average removal depth in ~~these areas would range~~the identified hot spots ranges from 24 to 40 inches. The estimated removal depth for each area was calculated using the average bottom depth of the sample intervals containing total PCBs greater than 1 mg/kg (i.e., to an RAL of 1) within the remediation area boundaries shown on Figures 3-1 through 3-3. The total volume that would be removed in S-3A is approximately 18,200 cy (quantities in cost estimates include adjustments because of constructability considerations). Surveying methods and GPS-equipped earth-moving ~~equipment~~equipment would be used to verify that specified removal depths have been achieved. Residuals management in the form of a thin-layer cap addition would occur in approximately 50% of the area is assumed for the purpose of cost estimating. The need for and effectiveness of a thin-layer cap would be evaluated in the remedial design.

Commented [A4]: Increase to add KPT20 volume

Ancillary activities such as site access and preparation, debris removal, monitoring during construction, material and equipment staging, removed sediment dewatering and handling, water management, post-removal confirmation sampling, and dredged-sediment transport and disposal would be required to support remedy implementation under this alternative. S-3A is estimated to require 1 to 2 years to complete (assuming a construction season of 8 out of 12 months) following design, permitting, and obtaining the necessary land access agreements.

Typical silt curtain controls and surface water monitoring would be employed for turbidity and PCB migration from removal areas. Restoration would be conducted where disturbances to the existing vegetation and natural habitats would occur within upland, wetland, and riverbank areas due to the construction of support facilities and implementation of remedial activities. Excavated channel edges would be stabilized, and formerly vegetated upland areas that are disturbed for river access would be restored in kind with topsoil and revegetated with native seed mixes and woody plantings.

The LTM and ICs/ECs would be implemented over an assumed 30-year period throughout Area 1 as described for Alternative S-2 for MNR documentation following completion of the sediment removal action. Inspections and maintenance of the restored areas would be included as part of the visual inspection program.

4.3.2 S-3A Alternative Evaluation

4.3.2.1 Overall Protection of Human Health and the Environment

Removing PCB-containing sediment in the Area 1 hot spot areas and Crown Vantage side channel would provide protection of human health and the environment by reducing overall PCB exposure risk to humans and ecological receptors and would support the reduction in PCB concentrations in fish tissue over time.

~~The~~ As part of this alternative evaluation, current and ~~predicted~~ post-remediation SWAC estimates for ~~Sections 2, 3~~the remedial reach were calculated using several methods to assess the potential range in the SWACs. The details of this SWAC analysis are presented in Appendix J, and ~~4~~the overall results are summarized in Table 4-~~2.~~3.

Four methods were applied to calculate pre- and post-remediation SWACs for the remedial reach. The ~~post-remediation SWAC predictions for Alternative S-3A are based on the removal of~~ first three applied GIS-based approaches using stream tube PCB concentrations are similar to the method described in Section 1.3.1.1. The fourth was an arithmetic approach using statistical average PCB concentrations to represent the hot spot areas ~~KRT4, KRT5/FF~~ and the remainder of the remedial reach (i.e., outside of the hot spots). Each method was used to calculate SWACs for four depth intervals: 0 to 6 inches, 6 to 12 inches, 12 to 24 inches and a combined 0 to 24 inches. A summary of each calculation method is provided below:

- Method GIS-3A: Stream tube method as described in Section 1.3.1.1 applied to the remedial reach. Stream tube PCB concentrations were limited to the unbiased sediment transect dataset, and whole stream tubes intersecting the hot spots to be excavated were replaced with a post-excavation PCB concentration of 1 mg/kg.
- Method GIS-3B: Stream tube divisions were extended or truncated to fit the hot spot excavation boundaries as shown in Figures 3-1 through 3-3. Stream tube PCB concentrations were limited to the unbiased sediment transect dataset. Only truncates stream tube segements within the excavation footprints were replaced with a post-excavation PCB concentration of 1 mg/kg.
- Method GIS-3C: Stream tube divisions were extended or truncated to fit the boundaries of the hot spot excavation footprints. PCB concentrations for stream tube segments inside of the hot spot boundaries prior to excavation were based on averages calculated using all available data within the hot spot footprint. Only the truncated stream tube segments within excavation footprints were replaced with a post-excavation PCB concentration of 1 mg/kg.
- Arithmetic Method: Two average weighted concentrations were calculated. The first was the average of all sediment data falling within the excavation footprints of hot spots KPT-19, ~~KPT19,~~ KPT-20, KRT-4, KRT-5, and S-IM1~~, and allows for two additional removal~~. The second was the average concentration of all sediment data in the remedial reach outside of the hot spot. The arithmetic SWAC was then calculated using the areas ~~in Section 3 to be identified during remedial design sampling. A value of 1 mg/kg is applied to the excavated sample locations included in the recalculated SWAC based on excavation to an RAL of 1. The~~ for the hot spot areas and area of remainder of the remedial reach. The post-remediation SWAC ~~calculations otherwise follow~~applied a concentration of 1 mg/kg to the ~~same protocols, and use~~combined area of the ~~same~~hot spots.

The SWAC estimate considered to be the most representative of site conditions based on the available data ~~set as described in Section 1.3.1.1~~is Method GIS-3C. This SWAC method considers all of the data within each hot spot (reflects known hot spot size and magnitude), and ~~Appendix B. A~~limits post~~-~~ remedial reductions to the actual excavation area (not whole stream tubes). By this method, the surface (0-6 inch) PCB SWACs for the remedial reach pre- and post-Alternative S-3A remediation ~~SWAC is not presented for Crown Vantage side channel because all of the affected stream tubes in that area would be removed. Post removal concentrations would~~were calculated to be ~~similar to that of the coarse base river bottom material uncovered during the TCRAs. This remaining material typically had very low PCB concentrations (0.~~1.76 and 1.09 mg/kg, respectively (Tables 4-3). The arithmetic approach provides a method for calculating LCL and UCL bounds (symmetcical 95% confidence limits representing 2.5% to 97.5% confidence around the mean) on these SWACs. The pre-remediation LCL-UCL PCB SWAC range for the 0 to 6-inch interval in the remedial reach is 0.49 to 2.33 mg/kg~~ or less)~~.. The post-remediation LCL-UCL PCB SWAC range following Alternative S-3A remedial action is 0.35 to 1.06 mg/kg. The best estimate is slightly above the UCL calculated, which is reasonable given the use of two different SWAC calculation methods, and that (by definition), a 95% confidence interval will not contain 1 out of 20 values. The difference between these two methods is that one weights each hot spot area separately and the other weights the aggregate average hot spot concentration. The UCL is based on the latter, which has lower variability.

~~Because of the calculation methodology (which uses transect data from 0 to 24 inches in depth, without step out or replacement data for re-sampled locations as agreed upon by the SWAC Work Group), the pre- and post-remediation SWAC estimates for Section 2 are the same (Table 4-2). Sample values with relatively higher PCB concentrations in the KPT19 hot spot area are either deeper than 24 inches or identified as step out samples. Therefore, samples associated with the KPT19 hot spot area are not included in either the Pre- or Post-removal SWAC. As a result, this hot spot removal does not change the theoretical SWAC value in Section 2. The post-remediation SWACs in Section 4 exhibit reductions, but they are relatively small because of similar artifacts of the calculation methodology. These post-remedial SWACs in Sections 2 and 4 are reasonable given that the overall SWACs in these sections are already relatively low, and the isolated hot spot removals would not be expected to significantly change averages over the entire area.~~

~~The pre- and post- remediation SWAC changes in Section 3 are more pronounced, with values for all intervals falling at or below 1 mg/kg following excavation. As noted above, sampling in Section 3 will be performed during remedial design to evaluate if and where additional removal areas between the historical transects would be included~~ Future fish tissue concentrations under this alternative ~~(Section 3.2.1.2). It is assumed that two additional hot spots will be identified and removed based on the remedial design sampling results.~~

~~Future fish tissue concentration projections for this alternative were calculated based on the following assumptions:~~

- ~~MNR would continue at 2% per year until remedial design is completed (i.e., two years from ROD issuance).~~

have been projected based on a range of recovery rates that were calculated using the historical trend rates as described for Alternative S-2. For Alternative S-3A, the rate of decline was set equal to that for MNR under S-2 during the two years preceding the start of remedial action. Two years were allocated for development of the ROD and remedial design. It is assumed that fish tissue concentrations would remain constant ~~for two years while the remedy is implemented~~ during remedial action implementation due to sediment resuspension ~~during removal, habitat destruction~~effects, etc. during Alternative S-3A implementation (assumed 2 years).

- ~~Following completion of remedial activity under this Alternative, fish tissue concentration would decline at 3% per year (i.e., assuming a 1% per year increase over the projections for MNR alone). Actual rates may be higher or lower.~~

~~For alternative S-3A, smallmouth bass fillet concentrations are projected to meet the PRG in 5 years following ROD issuance in the urban areas and in 16 years in the dam areas. Smallmouth bass whole-body concentrations are projected to meet the goal in the urban areas in about eight years, and already meet the PRG in the dam areas. Common carp fillets are projected to meet the PRGs in the urban and dam areas in 34 and 32 years, respectively (Table 4-1). Timeframes start at ROD issuance. Natural recovery is expect to occur prior to ROD issuance, so that the timeframes provided are conservative and may be less than the values provided.~~

~~Upper and lower bounds on fish tissue projections were calculated assuming 0% and 7.7% rates of decline for MNR and 1% and 8.7% rates of decline following implementation of remediation (i.e., 1% increase over MNR rates of decline following remediation). These calculations are presented in Appendix I. At the upper bound, fish tissue concentrations change slowly and PRGs in smallmouth bass and carp take up to 43 and 95 years, respectively, to reach their respective PRGs (Table I-1). At the lower bound, all three fish tissue types in both urban and dam areas would meet PRGs within 14 years (Table I-2).~~

Following completion of remedial action, the projections include a step down and then a range of recovery rates to estimate the time until fish tissue concentrations reach target concentrations. Applying a step down phase within the time projection is based on the occurrence of a step down in tissue concentrations following remediation at the Bryant Mill Pond TCRA, which is within the Kalamazoo watershed (Enclosure 1 of MDEQ comments; MDEQ, 2013) and observations made at the Fox River (reference). Step downs with upper and lower bounds were estimated to account for the potential variability in the outcome and limitations of data sets gathered over varying conditions and time. The step down is a function of the change in SWAC (pre- and post-remediation) for the remedial reach and an adjusted BSAF. Three sources of biota-sediment accumulation factors (BSAFs) were used to provide a mid range, and upper/lower bound: (1) a loglinear regression equation developed for the relationship between fish tissue and sediment concentrations for the Kalamazoo River (Enclosure 1 of MDEQ comments; MDEQ, 2013), (2) a BSAF approximation from the Bryant Mill Pond TCRA, and (3) BSAFs developed for the ecological and human health risk assessments for the Kalamazoo River (CDM 2003a, 2003b). Bryant Mill Pond TCRA results indicated an order-of-magnitude reduction in fish tissue PCB concentrations for a two-order magnitude reduction in PCB sediment concentrations (i.e., a ratio of 0.10).

The BSAFs reported by CDM in 2003 were 0.444 for SMB fillet, 1.0 for SMB YOY whole body, and 0.641 for common carp fillet. These BSAFs were adjusted downward using a percent diffference based on the change in SWAC so that negative or unrealistic fish tissue concentration step downs would not be generated. The adjustment to the BSAF associated with the step down is a ratio of the difference between pre- and post-remedial SWACs to the pre-remedial SWAC. This ratio represents an expected decrease in the BSAF that corresponds with lower PCB concentrations in fish tissue and sediment. A more detailed description and

Commented [A5]: Insert reference

equations used in the step down calculations are provided in Appendix I. The step down value in mg/kg is reported for each fish type for each remedial alternative in Table 4-0.

The upper, mid-range, and lower bound step downs were calculated using the three methods paired with the LCL, best estimate, and UCL SWAC ranges for this alternative (Table 4-3).

The percent decline in fish tissue PCB concentrations following the step down were selected as follows (the percentage for each fish type and river section are presented in Table 4-0):

- Upper Bound: The AAPD from the mid-range scenario for MNR was selected.
- Mid-range: An AADP was used with a power equation that results in a curve with a slope that decreases over time. The selected AAPD was greater than the mid-range AAPD for MNR and less than the AAPD for the lower bound.
- Lower Bound: The UCL of the statistically significant highest AAPD from MNR was retained for the "lower bound".

Tables 4-1a therough 4-1c list projections of the time to achieve fish tissue goals for the three fish tissue types (SMB fillets, SMB YOY whole body, and common carp fillets) for each remedial alternative for mid, upper, and lower bound approximation of time. Details of the fish projection methodology with tabulations of the calculation inputs and results are presented in Appendix I.

Time projections to meet fish tissue goals under Alternative S-3A are measured from the start of remedial action implementation. Under this alternative, fish tissue concentrations throughout Area 1 (both urban and dams areas) are projected to meet the 1 x 10^{-5} carcinogenic risk goal for protection of human health (0.042 mg/kg) within 35 years (mid approximation of time) for smallmouth bass and 120 years (mid approximation of time) for common carp. Whole-body SMB YOY concentrations are projected to meet the ecological risk goal (0.6 mg/kg for mink) in Area 1 within 2 years as a mid approximation of tme. Mid approximations of times to reach other risk-based goals are listed in Tables 4-1a through 4-1c, and are shorter than those stated above. Fish projections for each fish type for S-3A are provided in Figures 4-2a through 4-2c.

For river Sections 1, 5, 6, 7, 8, and Mill Race, the sediment conditions for this Alternative are the same as presented for MNR. The overall SWAC (0-24 inches) in Sections 2 and 4 ~~is at or near the PRG and would be improved, but current SWAC methodology predictions (using available transect data) to not reflect the full benefit of the hot spot removals in these areas~~outside the remediation reach is at or below the sediment PRG. The post-excavation SWAC estimates indicate that ~~Section 3 averages would drop to near or below 1 mg/kg~~the remediation reach average concentrations in the 0 to 6 inch interval would be 1.09 mg/kg with a LCL and UCL of 0.35 and 1.06 mg/kg, respectively. The Crown Vantage side channel impacted sediment would be removed ~~(~~, and the post-remediation SWAC would be less than 1 mg/kg.

Remediation under Alternative 3A would augment the natural recovery observed following the removal of most PCB inputs to Area 1 through the TCRAs and other OU actions as documented by declining fish tissue trends, improved surface water quality, etc. Time to reach overall sediment goals in Area 1 will be faster than under MNR, as removal immediately improves conditions in ~~Sections 2, 3, and 4~~the remedial reach, and would boost fish tissue recovery rates.

Removal of PCB-containing sediment would also serve to remove some other constituents detected in Area 1 sediment. Organic constituents and metals were detected in Area 1 sediment. Removal or capping would provide protection to ecological receptors from exposure to PCBs and these constituents as well. The collocation of non-PCB constituents with PCBs in the sediment does not imply that they came from a similar source area or that they are related to paper mill recycling processes. Rather, their collocation is likely a result of shared fate and transport mechanisms (ARCADIS 2012c).

4.3.2.2 Compliance with ARARs

Compliance with ARARs for Alternative S-3A is similar to that for S-2. A ~~waiver for the TSCA ARARs~~ risk-based equivalency demonstration would be required for compliance with TSCA ARARs to allow isolated PCB concentrations greater than 50 mg/kg to remain in place~~ and to allow PCB concentrations less than 50 mg/kg to remain in place without deed/access restrictions~~. It is assumed that appropriate control measures would be implemented during construction such that the substantive requirements of the action- and location-specific ARARs would be achieved. Permits are not required to be obtained under CERCLA, but the substantive requirements of those permits must be met.

The time to comply with human health and ecological exposure risk targets (chemical-specific ARARs) in fish for the proposed hot spot areas and Crown Vantage side channel removal alternative S-3A is estimated to be ~~16~~35 years in smallmouth bass and ~~34~~120 years in common carp ~~starting from~~after the ~~time~~start of ~~ROD issuance~~remedial action for the mid time approximation (Table 4-1). Time to reach overall sediment goals in Area 1 is expected to be faster than the overall fish tissue recovery periods, given that the sediment concentrations in much of Area 1 are already below or near the PRGs, as noted above.

4.3.2.3 Long-Term Effectiveness

Long-term effectiveness of S-3A following removal of the hot spot areas and Crown Vantage side channel sediment is similar to that for S-2. The benefit of contaminated sediment excavation in the ~~removals in Sections 2, 3, and 4~~ remedial reach is overall SWAC reduction ~~primarily in Section 3~~to reduce PCB exposure and improve fish tissue concentrations, and removal of buried PCB-containing sediment that could be re-exposed or eroded in the future. The result of the SWAC reduction is a projected ~~increases~~increase in the rates of decline in fish tissue and in overall Area 1 sediment PCB concentrations. With the expected increased rate of fish tissue recovery, the time to reach fish tissue ~~targets~~goals for a 1×10^{-5} risk target is estimated at ~~16~~35 years in smallmouth bass and ~~34~~120 years in common carp ~~starting from~~after the ~~time~~start of ~~ROD issuance~~remedial action for the mid time approximation (Table 4-1).

4.3.2.4 Short-Term Effectiveness

Removal of hot spot areas and Crown Vantage Side Channel materials ~~result~~results in immediate reductions in sediment SWACs. Temporary impacts to stream bank and channel bottom habitats during removal are localized and reversible. Risks to workers during excavation activities would be controlled through safe work practices and training. Risk to the public due to disruptions and intrusions into local communities, equipment and truck traffic, material handling and staging operations, etc. during implementation of this work would also be managed by monitoring in active work areas, safe work practices, and training.

4.3.2.5 Reduction in TMV through Treatment

Treatment, other than dewatering, would not be performed. However, this Alternative would reduce the volume of impacted sediment in the river.

4.3.2.6 Implementability

Removal under this option requires the construction of roads and staging areas to access the various hot spot locations and the Crown Vantage Side Channel. Removal and dewatering would be performed using conventional equipment, which is readily available. Transport of dewatered material to an approved off-site landfill would be required. Remedial design is anticipated to take two years following ROD issuance, with implementation estimated at between one and two years.

4.3.2.7 Cost

The S-3A cost estimate is presented in Table 4-4. A present worth analysis was performed using a discount rate of 7% in accordance with USEPA guidance (USEPA 1988a). This alternative includes the removal of ~~four~~five hot spot areas and Crown Vantage side channel. For costing purposes, it was assumed that up to two additional removal areas may also be identified in ~~Section 3~~the remedial reach during remedial design, and a range of costs representing ~~four~~five to ~~six~~seven hot spot areas is presented based on the average removal cost calculated for ~~KPT19, KRT4, KRT5~~the larger known hot spots KPT-19, KRT-4, KRT-5/FF-19, and S-IM1. The average cost per hot spot area removal is $2,400,000. An assumption has been made that allows for the removal of up to two additional hot spots as part of this alternative has been made for the purpose of providing a possible cost range for comparison with other remedial alternatives in this FS. The actual number and extent of hot spots in the remedial reach requiring remedial action will be determined and agreed upon by USEPA and MDEQ during remedial design and prior to implementation of remedial action. A list of cost assumptions and unit rates are provided in Appendix H.

Alterative S-3A	Present Worth	$10,600,000 to $15,400,000
	Total Cost	$11,600,000 to $16,400,000

Commented [A6]: Update for KPT20 and LTM

4.4 ALTERNATIVE S-3B: REMOVAL OF HOT SPOT AREAS, IN-SITU CAPPING OF CROWN VANTAGE SIDE CHANNEL, ICS/ECS, AND MNR

4.4.1 S-3B Description

The scope of this Alternative S-3B would include the activities described for alternative S-3A for the ~~four~~five hot spot areas in the remedial reach plus capping of the Crown Vantage side channel (Figures 3-1 through 3-3). The cap area for the Crown Vantage side channel is approximately 1.2 acres. Ancillary activities and support areas would be similar to that described for alternative S-3A.

The Crown Vantage side channel was selected for capping activities because this area represents an environment that is amenable to capping. It lies outside the main river channel, and is a backwater except during flooding events. The channel would be cut off from its connection to the river at the downstream end, capped, and armored to prevent erosion during floods, ice scour, etc. The cap would be designed in accordance with USEPA and USACE guidance to provide long-term isolation and provide for stability, integrity, and protectiveness.

Cap installation would be performed from land using conventional earth moving equipment. The engineered cap would consist of a geotextile layer and a 12-inch-thick sand isolation layer overlain by a 6-inch gravel armor layer. The final cap composition, configuration, and transitions would be determined during remedy design.

LTM would the same as for alternative S-3A over an assumed 30-year MNR period, with additional inspection and maintenance for the Crown Vantage side channel area cap (annual for the first five years, then every five years for the remainder of the period; plus additional inspections after major storm/flooding events, as necessary. Additional ECs for erosion control are assumed within the 30-year evaluation period.

4.4.2 S-3B Alternative Evaluation

4.4.2.1 Overall Protection of Human Health and the Environment

Protectiveness of this alternative is the same as for alternative S-3A. Capping of the Crown Vantage side channel provides physical and chemical isolation of PCB-containing sediment similar to removal to prevent human and ecological exposures.

4.4.2.2 Compliance with ARARs

Compliance with ARARs for Alternative S-3B is similar to that for S-3A. The time to comply with fish tissue targets for human health and ecological exposure risk for alternative S-3B is estimated to be the same as S-3A (i.e.,~~16~~35 years in smallmouth bass and ~~34~~120 years in common carp, following ~~ROD issuance~~the start of remedial action for the mid time approximation, Table 4-1).

4.4.2.3 Long-Term Effectiveness

Long-term effectiveness of this alternative is predicted to be similar to S-3A.

4.4.2.4 Short-Term Effectiveness

The short-term effectiveness of this alternative is predicted to be similar to S-3A, with slightly less construction worker and public risk for capping of the Crown Vantage side channel as opposed to excavation because it avoids PCB residuals handling, transport, and disposal operations for that area.

4.4.2.5 Reduction in TMV through Treatment

Treatment, other than dewatering, would not be performed. However, capping in the Crown Vantage side channel would reduce the mobility of sediment containing PCBs. Mass and toxicity would remain the same. Reduction in TMV for excavated material would be as described in S-3A.

4.4.2.6 Implementability

Implementability is the same as for S-3A; capping is implementable with conventional equipment.

4.4.2.7 Cost

The S-3B cost estimate is presented in Table 4-5. The cost ranges for removing ~~four~~five to ~~six~~seven hot spots are the same as presented for S-3A, plus the cost for capping rather than excavating Crown Vantage side channel. A present worth analysis was performed using a discount rate of 7% in accordance with USEPA guidance (USEPA 1988a). A list of cost assumptions and unit rates are provided in Appendix H.

Alterative S-3B	Present Worth	$9,600,000 to $14,400,000
	Total Cost	$10,700,000 to $15,500,000

Commented [A7]: Update costs for additional hot spot

4.5 ALTERNATIVE S-4A: REMOVAL OF HOT SPOT AREAS, CROWN VANTAGE SIDE CHANNEL AND SECTION 3 RIVER EDGES, MNR, ICS, AND ECS

4.5.1 S-4A Description

The scope of this alternative includes the activities described for alternative S-3A plus the addition of excavating sediment along the edges of the Section 3 river channel that exceed 1 mg/kg per the geomorphic analysis described in Section 3.2.1.1 (Figure 3-7). The total estimated removal volume for the ~~four~~five hot spot areas, Crown Vantage side channel, and the Section 3 channel edges is 62,600 cy, spanning approximately 15 acres (quantities in cost estimates include adjustments because of constructability considerations).

Commented [A8]: Update for KPT20

Additional sampling of the remediation reach would be performed as part of the remedial design phase to further delineate the removal boundaries. Sampling would be conducted in accordance with a USEPA-approved work plan. Identification and quantification of remediation areas within the remedial reach would require concurrence by USEPA and MDEQ prior to implementation of remedial action.

The edge removal in Section 3 would span roughly 80% of each bank, or 1.4 miles along each side of the river. Ancillary activities would be similar to those described for alternative S-3A with additional staging and access roads to for edge removals. Design planning, permitting, and obtaining property access agreements would be required to construct access roads and staging areas along both sides of the river. Surveying would be used to verify that specified removal depths are achieved. It is assumed that a thin layer sand cap (3-6 inches) would be placed over the exposed bottom sediment following completion of excavation to aid residual management~~.~~ for the purpose of cost estimation. The need for type of, and effectiveness of a thin layer cap would be evaluated during remedial design. Restoration would be conducted where disturbances to the existing vegetation and natural habitats occurred within upland, wetland, and riverbank areas due to the construction of support facilities and implementation of remedial activities. Excavated channel edges would be protected with erosion controls and/or rock armoring (as necessary), and formerly vegetated upland areas disturbed for river access would be restored in kind with topsoil and revegetated with native seed mixes and woody plantings.

Time for construction completion is estimated at 4 years following ROD issuance and remedial design, assuming eight months to a construction season. Remedial design is expected to require 2 years. LTM would be the same as for alternative S-3A over an assumed 30-year period, with additional ECs inspection and erosion control maintenance for the Section 3 edges and restored access and support areas.

4.5.2 S-4A Alternative Evaluation

4.5.2.1 Overall Protection of Human Health and the Environment

Adding the removal of the river edges in Section 3 provides similar overall protection to human health and the environment as described for alternative S-3A. It would reduce overall exposure risk to humans and ecological receptors and support the reduction in PCB levels in fish over time.

~~Projected future fish tissue trends following ROD issuance would be similar to those described for alternative S-3A (Tables 4-1, I-1, and I-2), but extended by about two years to allow for the longer implementation time (i.e., 4 years for Alternative S-4A as opposed to two years for Alternative S-3A).~~

Current and post-remediation SWAC estimates for the remedial reach were calculated using several methods to assess the potential range in the SWACs. The details of this SWAC analysis are presented in Appendix J, and the overall results are summarized in Table 4-3.

For remedial Alternative S-4A, seven methods were applied to calculate SWACs for the remedial reach. The first six applied GIS-based approaches used the stream tube method described in Section 1.3.1.1 over the remedial reach. The seventh was an arithmetic approach using average PCB concentrations to represent the hot spot areas, river edges (30 feet from each bank) and the remainder of the remedial reach (i.e., outside of the hot spots and edges). Each method was used to calculate SWACs for four depth intervals: 0 to 6 inches, 6 to 12 inches, 12 to 24 inches and a combined 0 to 24 inches. A summary of each calculation method is provided below:

- Method GIS-4A: Stream tube method as described in Section 1.3.1.1 applied to the remedial reach. Stream tube PCB concentrations were limited to the unbiased sediment transect dataset. Whole stream tubes intersecting the hot spots and whole stream tubes with any part within 30 feet of the river bank were replaced with a post-excavation PCB concentration of 1 mg/kg.
- Method GIS-4B: Stream tube divisions were extended or truncated to fit the hot spot excavation boundaries as shown in Figures 3-1 through 3-3. Stream tube PCB concentrations were limited to the unbiased sediment transect dataset. The truncated stream tube segments within excavation footprints and whole stream tubes with any part within 30 feet of the river bank were replaced with a post-excavation PCB concentration of 1 mg/kg.
- Method GIS-4C: Stream tube divisions were extended or truncated to fit the boundary of hot spot excavation footprints. PCB concentrations for stream tube segments inside of the hot spot boundaries were calculated using all available data within the hot spot footprint. The truncated stream tube segments within excavation footprints and whole stream tubes with any part within 30 feet of the river bank were replaced with a post-excavation PCB concentration of 1 mg/kg.
- Method GIS-4D, 4E, and 4F: This method is similar to GIS-4A, 4B, and 4C, respectively, but with edge stream tubes sliced longitudinally so that post-excavation edge tube replacement includes only the portions of the tubes within 30 feet of the river bank.
- Arithmetic Method: Three weighted average concentrations were calculated. The first was the average of all sediment data falling within the excavation footprints of hot spots KPT-19, KPT-20, KRT-4, KRT-5, and S-IM1. The second was the average concentration of all sediment data falling within 30 feet of either river edge in Section 3. The third was the average concentration of all sediment data in the remedial reach outside of the hot spot areas and further than 30 feet from the river bank in Section 3. The arithmetic SWAC was then calculated using the respective areas for the combined hot spot areas, 30-foot river edges (both sides of the river in Section 3), and the remainder of the remedial reach. The post-remediation SWAC applied a concentration of 1 mg/kg to the hot spots and river edges in Section 3.

The SWAC estimate considered to be the most representative of site conditions based on the available data is from Method GIS-4F. It considers all of the data within each hot spot (reflects known hot spot size and magnitude), considers only the portions of the “edge tubes” actually within 30 feet of the river bank, and limits post remedial reduction to the actual proposed excavation area (not whole stream tubes). By this method, the surface (0-6 inch) PCB SWACs for the remedial reach pre- and post-Alternative S-4A remediation were calculated to be 1.76 and 0.60 mg/kg, respectively (Tables 4-3). The arithmetic method provides a means for calculating LCL and UCL (symmetcical 95% confidence limits representing 2.5% to 97.5% confidence around the mean) on these SWACs. The pre-remediation LCL-UCL PCB SWAC range for the 0 to 6-inch surface interval in the remedial reach is 0.49 to 2.23 mg/kg. The post-remediation LCL-UCL PCB SWAC range following Alternative S-4A remedial action is 0.34 to 0.90 mg/kg.

Future fish tissue concentrations under this alternative have been projected based on a range of recovery rates that were calculated based on the historical trend rates as described for Alternative S-2 and S-3A. For Alternative S-4A, the percent decline was set equal to that for MNR under S-2 during the two years preceding the start of remedial action. Two years were allocated for development of a ROD and remedial design. It was assumed that fish tissue concentrations would remain constant due to sediment resuspension effects, etc. during Alternative S-4A implementation (4 years).

Following completion of remedial action, the projections include a step down and then a range of recovery rates. The basis for and method of calculating the step down is the same as that applied to S-3A. The pre-and post-remedial SWACs for the remedial reach used in the step down equation are provided in Table 4-3.

The percent decline in fish tissue PCB concentrations following the step down were selected as follows:

- Upper Bound: The AAPD for the mid-range scenario for MNR was selected.
- Mid-range: An AADP was generated from a power equation with produces a curve with a slope that decreases over time. The selected AAPD was greater than the mid-range AAPD for MNR and less than the AAPD for the lower bound.
- Lower Bound: The UCL of the statistically significant highest AAPD from MNR was retained for the lower bound.

The specific rates for each fish type and river area are listed in Table 4-0. Table 4-1 lists projections of the time to achieve fish tissue goals for the three fish tissue types (SMB fillets, SMB YOY whole body, and common carp fillets) for each remedial alternative. Details of the fish projection methodology with tabulations of the calculation inputs and results are presented in Appendix I.

Time projections to meet fish tissue goals under Alternative S-4A are measured from the start of remedial action implementation. Under this alternative, fish tissue concentrations throughout Area 1 (both urban and dams areas) are projected to meet the fish tissue goal associated with a 1×10^{-5} carcinogenic risk for human health (0.042 mg/kg) within 33 years for smallmouth bass and 115 years for common carp for the mid time approximation. Whole-body SMB YOY concentrations are projected to meet the ecological risk goal (0.6 mg/kg for mink) in Area 1 within 4 years for the mid time approximation. Times to reach other risk-based goals are listed in Tables 4-1a through 4-1c, and are shorter than those stated above. Fish projections for each fish type for S-4A for the mid, lower, and upper bound time to reach the fish tissue goals are provided in Figures 4-3a through 4-3c.

For river Sections 1, ~~2, 4,~~ 5, 6, 7, 8, Sections 2 and 4 outside the remedial reach, Mill Race, and Crown Vantage side channel, sediment recovery conditions for this Alternative are the same as presented for S-3A. The post-~~excavation~~remedial SWAC estimates for Alternative S-4A indicate that Section 3 SWACs for the 0 to 6 inch interval would be ~~just below the~~ 0.~~33~~60 mg/kg ~~PRG~~with an LCL and UCL of 0.34 and 0.90 mg/kg, respectively...This range of post-remedial SWACs is similar to that calculated for S-3A.

4.5.2.2 Compliance with ARARs

Compliance with ARARs for Alternative S-4A is similar to that for S-~~2~~3A. It is assumed that appropriate control measures would be implemented during construction such that the substantive requirements of the action- and location-specific ARARs would be achieved. Permits are not required to be obtained under CERCLA, but the substantive requirements of those permits must be met.

The time to comply with human health and ecological exposure risk targets in fish for alternative S-4A is estimated to be ~~the same as for S-3A (i.e.,16~~,33 years in smallmouth bass and ~~34~~115 years in common carp following ~~ROD issuance —~~the start of remedial action for the mid time approximation (Table 4-1).

4.5.2.3 Long-Term Effectiveness

Long-term effectiveness of this alternative is predicted to be similar to S-3A. Added LTM and maintenance would be required for ECs to control erosion along the riverbanks and excavated channel areas. Ecological habitat recovery time would be lengthy due to the extent of disturbance in Section 3.

4.5.2.4 Short-Term Effectiveness

Removal of material results in reductions in sediment SWACs. Impact to habitat would be invasive such that much of the riverbank wooded habitat and channel habitat along the 1.7 miles of Section 3 would be destroyed. Restoration of vegetative cover and habitat/wildlife recovery would be lengthy. Excavated channel edges would be protected with erosion controls and/or rock armoring (as necessary). Risks to workers during excavation activities would be controlled through safe work practices and training. Risk to the public due to disruptions and intrusions into local communities, equipment and truck traffic, material handling and staging operations, etc. during implementation of this work also be managed by monitoring in active work areas, safe work practices, and training.

4.5.2.5 Reduction in TMV through Treatment

Treatment, other than dewatering, would not be performed. However, this Alternative would reduce the volume of impacted sediment in the river.

4.5.2.6 Implementability

This alternative requires the construction of roads and staging areas on both sides of Section 3 for edge excavation. Removal and dewatering will be performed through the use of conventional equipment, which is readily available. Transport of dewatered material to an approved off-site landfill would be required. Requires approximately two years more than Alternative S3-A to implement.

4.5.2.7 Cost

The S-4A cost estimate is presented in Table 4-6. The cost ranges for removing ~~four~~five to ~~six~~seven hot spots and Crown Vantage side channel are the same as presented for S-3A, plus the cost of excavating the Section 3 channel edges, estimated at about $20,400,000. A present worth analysis was performed using a discount rate of 7% in accordance with USEPA guidance (USEPA 1988a). A list of cost assumptions and unit rates are provided in Appendix H.

Alterative S-4A	Present Worth	$31,000,000 to $35,800,000
	Total Cost	$32,000,000 to $36,800,000

Commented [A9]: Update for KPT20 and LTM

4.6 ALTERNATIVE S-4B: REMOVAL OF HOT SPOT AREAS AND SECTION 3 CHANNEL EDGES, IN SITU CAPPING OF CROWN VANTAGE SIDE CHANNEL, ICS/ECS, AND MNR

4.6.1 S-4B Description

The scope of this alternative includes the activities described for alternative S-4A with capping of the Crown Vantage side channel (as described in alternative S-3B) instead of removal. The cap area for the Crown Vantage side channel is approximately 1.2 acres. Support areas and ancillary activities would be similar to those described in S-4A.

LTM would the same as for alternative S-3B over an assumed 30-year period, with additional inspection and maintenance for erosion controls.

4.6.2 S-4B Alternative Evaluation

4.6.2.1 Overall Protection of Human Health and the Environment

Protectiveness of this alternative is the same as for alternative S-4A. Capping of the Crown Vantage side channel provides physical and chemical isolation of PCB-containing sediment to prevent human and ecological exposures, providing protection similar to removal.

4.6.2.2 Compliance with ARARs

Compliance with ARARs for Alternative S-4B is similar to that for S-4A. The time to comply with human health and ecological exposure risk targets in fish for alternative S-4B is estimated to be the same as for S-4A (i.e.,~~16~~33 years in smallmouth bass and ~~34~~115 years in common carp following ~~ROD issuance —~~the start of remedial action for the mid time approximation, Table 4-1).

4.6.2.3 Long-Term Effectiveness

Long-term effectiveness of this alternative is predicted to be similar to S-4A.

4.6.2.4 Short-Term Effectiveness

The short-term effectiveness of this alternative is predicted to be similar to S-4A.

4.6.2.5 Reduction in TMV through Treatment

Treatment, other than dewatering, would not be performed. However, capping in the Crown Vantage side channel would reduce the mobility of sediment containing PCBs. Mass and toxicity would remain the same. Reduction in TMV for excavated material would be as described in S-4A.

4.6.2.6 Implementability

Implementability is the same as for S-4A; capping is implementable with conventional equipment.

4.6.2.7 Cost

The S-4B cost estimate is presented in Table 4-7. A present worth analysis was performed using a discount rate of 7% in accordance with USEPA guidance (USEPA 1988a). The cost ranges for removing ~~four~~five to ~~six~~seven hot spots and Section 3 river edges are the same as presented for S-4A, plus cost for capping rather than excavating Crown Vantage side channel. A list of cost assumptions and unit rates are provided in Appendix H

Alterative S-4B	Present Worth	$30,000,000 to $34,800,000
	Total Cost	$31,000,000 to $35,800,000

Commented [A10]: Add KPT20 and LTM

4.7 ALTERNATIVE S-5: AREA 1-WIDE REMOVAL (RAL 1), MNR, ICs, AND ECs

4.7.1 S-5 Description

Alternative S-5 includes excavation of sediment exceeding an RAL of 1 mg/kg total PCB throughout the river in Area 1. The extent of excavation required for S-5 was estimated in two ways to provide remediation area and volume ranges for evaluating this alternative. The lower bound was estimated using the stream tube geometry created for the Area 1 SWAC calculations. In this estimate, the total remediation area was calculated by summing individual stream tubes encompassing a sample location with a result exceeding the RAL. An excavation depth of 6, 12, 24, or 36 inches was assigned to each tube depending on the bottom depth of the deepest sample interval exceeding the RAL in a given stream tube. For RAL-exceeding sample intervals extending past 24 inches, an excavation depth of 36 inches was applied, because this value represents the average sample bottom depth of those intervals throughout Area 1. An excavation depth of 24 inches was applied throughout the Crown Vantage side channel. The lower bound excavation area and volume calculated for Alternative S-5 by this method are 140 acres and 300,000 cy, respectively.

The upper bound for this alternative was estimated by assuming a gross average of 12 inches would be excavated from all contiguous fine-grained sediment areas, estimated to be about 20% of the total Area 1 surface area (ARCADIS 2012a), plus half of the remaining surface area accounting for the medium and mixed/distributed coarse/fine-grained sediment areas. This amounts to 60% (i.e., 20% plus 40%) of the total surface area of Area 1, plus the Crown Vantage side channel area (excavated to a depth of 24 inches). The upper bound excavation area and volume estimated for Alternative S-5 were 300 acres and 490,000 cy, respectively.

Design planning, permitting, and obtaining property access agreements would be required to construct access roads and staging areas along both sides of the river throughout most of Area 1. Surveying would be used to verify that specified removal depths are achieved. A thin layer sand cap (3–6 inches) would be placed over the exposed bottom sediment following completion of excavation in approximately 50% of the area to aid residual management. Restoration would be conducted where disturbances to the existing vegetation and natural habitats occurred within upland, wetland, and riverbank areas due to the construction of support facilities and implementation of remedial activities. Excavated channel edges would be protected with erosion controls and/or rock armoring (as necessary), and formerly vegetated upland areas for river access would be restored in kind with topsoil and revegetated with native seed mixes and woody plantings.

Implementation of this alternative is estimated to require 18 to 30 years to complete working with one crew sequentially from upstream to downstream. To complete construction in a more reasonable time of 6 to 10 years, three crews would work simultaneously. Working three crews simultaneously would potentially result in cross-contamination through resuspension in one work area and migration into another. Typical silt curtain controls and surface water monitoring for turbidity and PCB migration from removal areas would be employed.

LTM would be the same as for alternative S-3A over an assumed 30-year period, with additional inspections and maintenance of ECs for erosion control.

4.7.2 S-5 Alternative Evaluation

4.7.2.1 Overall Protection of Human Health and the Environment

Removal of sediment exceeding 1 mg/kg PCBs in throughout Area 1 would provide protection of human health and the environment, but achieving protection would be hampered by the long construction period. It would reduce overall PCB SWAC concentrations and fish tissue concentrations over time.

The current Area 1 SWAC estimates are 0.59, 0.59, and 2.12 mg/kg in intervals 1, 2, and 3, respectively, and an overall SWAC (intervals 1, 2, and 3 combined) of 0.92 mg/kg. Post-excavation SWAC estimates for this alternative were calculated using the whole stream tube method as described ~~for alternative S-3A~~in Section 1.3.1.1, with a final PCB concentration of 1 mg/kg applied to all excavated stream tubes. The estimated post-remediation SWACs following excavation of sediment exceeding 1 mg/kg throughout Area 1 are 0.23, 0.17, and 0.15 mg/kg for intervals 1, 2, and 3, respectively, and an overall SWAC (intervals 1, 2, and 3 combined) of 0.22 mg/kg ~~(Table 4-2).~~. Post-remedial SWAC calculations for S-5 represents an Area-wide change in SWACs. Sediment PRGs would be achieved upon completion of excavation activities, and removal of PCB-containing sediment would also serve to remove other constituents detected in Area 1 sediment.

~~Future~~ Fish tissue concentration ~~projections for this alternative~~recovery percentages were calculated based on the ~~following assumptions:~~

- historical trend rates as described for Alternative S-2, S-3A, and S-4A. For Alternative S-5, the rate of decline was set equal to that for MNR ~~continues at 2% per year until~~ under S-2 during the two years preceding the start of remedial action. Two years were allocated for the development of the RPD and remedial design ~~is completed (i.e., the first 2 years after ROD issuance).~~
- ~~MNR rates decrease from 2% to 0% during construction~~. It is assumed that fish tissue concentrations would remain constant due to ~~extensive~~ sediment resuspension ~~during widespread excavation, habitat destruction~~effects, etc. ~~This is consistent with results following the Plainwell Impoundment and Plainwell Dam No. 2 TCRAs producing an apparent leveling off. It is anticipated that this effect would continue or be exacerbated by the extent and duration of sediment disruption for this alternative.~~

~~A~~ during Alternative S-5 implementation (10~~% step down in concentration is applied at the end of construction. A 10% step down is consistent with the step down observed for fish in Portage Creek following remedial action at Bryant's Mill Pond (Kern 2012).~~ years).

Following completion of remedial ~~activity, fish tissue concentrations decline at 3% per year (i.e., a 1% per year increase over~~ action, the projections include a step down and then a range of recovery rates. The basis for and method of calculating the step down is the same as that applied to S-3A. Rates of decline for PCB concentrations in fish tissue following the step down were selected as described for S-3A and as follows:

- Upper Bound: The AAPD from the mid-range scenario for MNR ~~alone). Calculations were also performed for a 5% post-~~was selected.
- Mid-range: An AADP was used with a power equation that results in a curve with a slope that decreases over time. The selected AAPD was greater than the mid-range AAPD for MNR and less than the AAPD for the lower bound.
- Lower Bound: The UCL of the statistically significant and highest AAPD from MNR was retained for the “lower bound”.

Table 4-1 lists projections of the time to achieve fish tissue goals for the three fish tissue types (SMB fillets, SMB YOY whole body, and common carp fillets) for each remedial ~~rate of decline to provide a range of outcomes. Actual rates of decline may be higher or lower~~alternative for the mid, lower, and upper time approximations. Details of the fish projection methodology with tabulations of the calculation inputs and results are presented in Appendix I.

~~For~~Time projections to meet fish tissue goals under Alternative S-5~~,~~ are measured from the start of remedial action implementation. Under this alternative, fish tissue concentrations throughout Area 1 (both urban and dams areas) are projected to meet the goal associated with the 1 x 10^{-5} carcinogenic target for protection of human health (0.042 mg/kg) within 57 years for smallmouth bass ~~fillet concentrations are projected to meet the PRG within about 12 years from ROD issuance in the urban areas (at both 3 and 5%),~~ and ~~in about 22~~121 years ~~(18 years at 5%) in the dam areas. Smallmouth bass~~for common carp for the mid time approximation. Whole-body SMB YOY concentrations are projected to meet the ecological risk goal (0.6 mg/kg for mink) in ~~the urban areas~~Area 1 within ~~about 12 years (at both 3~~10 years for the mid time approximation. Times to reach other risk-based goals are listed in Tables 4-1a through 4-1c, and ~~5%), and already meet the PRG in the dam areas. Common carp fillets are projected to meet the PRGs in the urban and dam areas in 42 and 39 years (30 and 28 years at 5%), respectively (Table 4-1). Timeframes start at ROD issuance. Natural recovery is expect to occur prior to ROD issuance, so that the timeframes~~are shorter than those stated above. Fish projections for each fish type for S-5 are provided ~~are conservative and may be less than the values provided.~~in Figures 4-4a through 4-4f for the mid, lower, and upper time approximations.

~~Upper and lower bounds on fish tissue projections were calculated assuming 0% and 7.7% rates of decline for MNR during design and the same 3% to 5% range in rates of decline following implementation of remediation. These calculations are presented in Appendix I. At the upper bound (with 0% MNR and 3% drop after excavation), smallmouth bass and carp tissue concentrations take up to 19 and 42 years to reach their respective PRGs (Table I-1). At the lower bound (7.7% MNR and 5% drop after excavation), all three fish tissue types in both urban and dam areas would meet PRGs within 30 years (Table I-2).~~

4.7.2.2 Compliance with ARARs

Applicable ARARs are discussed in Section 2.3 and listed in Tables 2-1 through 2-3. Alternative S-5 complies with ARARs~~, except that technical impracticability waivers would be required for~~. The ability of the remedy to meet Michigan NREPA water quality ARARs~~. These waivers would be required~~ in the long-term will be assessed in the future, such that future conditions may require a technical impracticability evaluation due to:

- Low-level continuing sources to the river that may sustain levels of PCBs in the water column (e.g., from the atmosphere, upstream areas and urbanized areas of the watershed, etc.)

- An inability to detect such low PCB concentration, as current typical water column detection limits are 1.0 to 0.2 ng/L

Discharge resulting from remediation activities such as dewatering would need to comply with applicable surface water quality standards.

The time to comply with human health and ecological exposure risk ~~targets~~target for a 1 x 10^{-5} carcinogenic risk target in fish for the Area 1-wide removal to an RAL of 1 for alternative S-5 would be ~~18 to 22~~54 years in smallmouth bass and ~~28 to 42~~115 years in common carp, following ~~ROD issuance~~the start of remedial action for the mid time approximation (Table 4-1). The sediment PRG would be met upon completion of excavation.

4.7.2.3 Long-Term Effectiveness

Long-term effectiveness of this option is good with respect to PCB levels, as sediment would meet goals upon completion of excavation, reducing ecological risk and future potential erosion and downstream migration. Overall protectiveness is not substantially improved over the less invasive options, nor is time to achieve overall goals. In addition, the harm to the ecosystem by implementing this alternative (both short- and long-term impacts) may out-weigh and outlast the benefits of PCB reduction achieved. Extensive destruction of habitat diminishes overall effectiveness.

4.7.2.4 Short-Term Effectiveness

Excavation throughout Area 1 would not be effective in the short term because of the prolonged construction period of at least 6 to10 years. Sediment resuspension and migration impacts during excavation would be increased with multiple crews working simultaneously to achieve the 6- to 10-year completion goal. Hard armoring required to control in-stream erosion will significantly alter the habitat in the river, and the destruction of sensitive riparian habitat for access and support areas to implement Alternative S-5 is invasive and extensive. Although restorative planting would be included for these disturbed areas, restoration may never fully replace the current quality of habitat that exists in and along the river. Public risk due to disruptions and intrusions into local communities, equipment and truck traffic, material handling and staging operations, etc. over the 6- to 10-year implementation of this work would also need to be managed by monitoring in active work areas, safe work practices, and training.

4.7.2.5 Reduction in TMV through Treatment

Treatment, other than dewatering, would not be performed. However, this Alternative would reduce the volume of impacted sediment in the river.

4.7.2.6 Implementability

The effort required to construct access roads and staging areas along the River would be extensive. Access along all 22 miles of Area 1 would be difficult to achieve both physically and administratively. Achieving work completion in 10 years (assuming 8 months to a construction season) requires three crews working simultaneously. The use of multiple crews would increase impacts from sediment resuspension and cross-contamination even with work flow progressing from upstream to downstream areas. If a single crew were to work downriver sequentially to avoid cross-contamination, construction would take approximately 30 years.

Removal and dewatering would be performed through the use of conventional equipment which is readily available. Transport of extensive quantities of dewatered material to an approved off-site landfill would be required. Truck traffic along local haul routes during removal would be frequent.

4.7.2.7 Cost

The S-5 cost estimate is presented in Table 4-8. A present worth analysis was performed using a discount rate of 7% in accordance with USEPA guidance (USEPA 1988a). A list of cost assumptions and unit rates are provided in Appendix H.

Alterative S-5	Present Worth	$133,000,000 to $221,000,000
	Total Cost	$ 201,000,000 to $335,000,000

4.8 COMPARATIVE ANALYSIS OF SEDIMENT ALTERNATVIES

The comparative analysis~~, scoring, and ranking~~ of the sediment remedial alternatives is presented in Table 4-9.~~ The seven criteria evaluated in this FS are scored on a scale from 1 to 5 with the higher score being more favorable. These scores are added to calculate a total score for each alternative. The maximum possible score is 35 points. The alternatives are ranked sequentially by total score from highest to lowest, with a ranking of 1 given to the highest score or most favorable alternative.~~ Alternatives S-3B and S-3A ~~were ranked~~are the ~~highest~~most favorable by comparison, with S-3B ~~ranked higher by two points~~being slightly more favorable because of a slightly lower cost and ease of implementability compared to S3A. However, S-3B would require long term maintenance because the material will be capped in placed. Both alternatives provide the highest overall cost/benefit because they significantly reduce SWACs in ~~Section 3~~the remedial reach with minimal habitat destruction and achieve PRGs in a timeframe of ~~16~~35 to ~~34~~120 years from ~~ROD issuance~~the start of remedial action, depending on fish species.

Alternatives S-4B and S-4A are ~~ranked third and fourth~~the next most favorable alternatives, respectively~~, with a difference of 2 points~~. S-4B ~~has been given the higher ranking due to~~ is slightly lower in cost and ~~ease in implementability.~~slightly more easily implemented. However, S-4B would require long term maintenance because the material will be capped in placed. These alternatives cost roughly 3 times more to implement than the ~~highest ranked~~most favorably compared alternative, S-3B, with minimal improvement in risk reduction and significant increase in habitat destruction. ~~Due to~~The range produced for the ~~minimal additional change in estimated~~LCL and UCL for the post-~~remediation SWAC, these alternatives do not reduce the overall~~ removal SWACs for S-3A and S-4A is very similar, with only a decrease in the mid approximation of time by two years to ~~achieve~~reach target fish tissue goals for smallmouth bass fillets ~~compared to S-3B/S-3A~~. Comparative plots of the fish tissue projections for ~~smallmouth bass~~SMB fillets, SMB YOY whole ~~-~~body ~~smallmouth bass~~, and common carp fillets for the different rates shown in Tables 4-1a through 4-1c are presented in Figures 4-1 through 4-~~3~~4.

S-2 (MNR) and S-1 (No Further Action) ~~are ranked 5th and 6th, with high criteria scores~~compare favorably only for cost and implementability. Both alternatives require ~~20~~87 to ~~46~~192 years (mid approximaten of time) from ROD issuance to meet PRGs (depending on fish species and risk target goal).

The Area 1-wide removal to RAL 1 is ~~ranked~~ the ~~lowest (seventh)~~least favorably compared of the seven alternatives. This is due to the long implementation time, intensive habitat destruction, long recovery time, and anticipated sediment suspension/migration issues resulting from simultaneous activity at multiple dredging sites. The extent of habitat destruction and restoration/maintenance activity required for this alternative would significantly prolong habitat recovery times. The fish projection plots (Figures 4-1 through 4-~~3~~4) depict the longer duration in fish tissue recovery for S-5 resulting from the long implementation time (10 years), despite the post-remediation step drop in fish tissue concentrations and higher potential rates of decline

~~(3% to 5%)~~ predicted following Area 1-wide excavation. This extensive removal effort spanning Area 1~~,~~ results in a slower overall rate of fish tissue improvement due to resuspension and increased ecological exposures during the 10 years required to implement this alternative compared to all other removal/capping alternatives.

Overall, remedial ~~alternative~~alternatives S-~~3B is scored higher~~3A/B compares most favorably because it preserves habitat~~,~~ and meets the threshold criteria for protecting human health and environment and meeting ARARs within a similar amount of time to S-4A/B(~~16~~33 to 35 years ~~for smallmouth bass~~SMB fillets and ~~34~~115 to 120 years for carp fillets, respecitively).

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Table 4-0a
Smallmouth Bass Fillet: Fish Projection Rate Percentages and Step Downs
Area 1, OU5 Kalamazoo River

S-2 (Includes Urban and Dam)						
	Urban Area			Dams Area		
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
MNR	0%	3.4%	5.1%	0.33%	2.3%	4.1%
Recovery	0%	3.4%	5.1%	0.33%	2.3%	4.1%

Notes:
Percentages with no (explanation) calculated from the log-linear regression

S-3 (Includes Urban Only)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0%	3.4%	5.1%	--	--	--
2 Year Step Down (mg/kg)	0.0063	0.032	0.066	--	--	--
Recovery (%)	3.4%	4% (power)	5.1%	--	--	--

Notes:
Used SWACs based on GIS and Arithmetic approaches for Remedial Reach (see Table 4-3 for SWAC values)
-- Not calculated
Percentages with no (explanation) calculated from the log-linear regression

S-4 (Includes Urban Only)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0%	1.9%	5.1%	--	--	--
4 Year Step Down (mg/kg)	0.0067	0.056	0.076	--	--	--
Recovery (%)	3.4%	4% (power)	5.1%	--	--	--

Notes:
Used SWACs based on GIS and Arithmetic approaches for Remedial Reach (see Table 4-3 for SWAC values)
-- Not calculated
Percentages with no (explanation) calculated from the log-linear regression

S-5 (Includes Urban and Dam)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0%	1.9%	5.1%	0.33%	2.3%	4.1%
10 Year Step Down (mg/kg)	0.013	0.051	0.075	0.023	0.092	0.14
Recovery (%)	3.4%	4.5% (power)	5.1%	2.3%	4% (power)	4.1%

Notes:
Used Area 1 Wide SWAC (see Section 4.7.2.1)
Percentages with no (explanation) calculated from a log-linear regression

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Table 4-0b

Smallmouth Bass Whole Body (Young of Year): Fish Projection Rate Percentages and Step Downs

Area 1, OU5 Kalamazoo River

S-2 (Includes Urban and Dam)						
	Urban Area			Dams Area		
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
MNR (%)	0%	3.2%	5.7%	6.3%	7.5%	8.9%
Recovery (%)	0%	3.2%	5.7%	6.3%	7.5%	8.9%

Notes:
SWAC Area 1 Wide
Percentages with no (explanation) calculated from the log-linear regression

S-3 (Includes Urban Only)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0%	3.2%	5.7%	--	--	--
2 Year Step Down (mg/kg)	0.021	0.16	0.31	--	--	--
Recovery (%)	3.2%	4% (power)	5.7%	--	--	--

Notes:
Used SWACs based on GIS and Arithmetic approaches for Remedial Reach (see Table 4-3 for SWAC values)
-- Not calculated
Percentages with no (explanation) calculated from the log-linear regression

S-4 (Includes Urban Only)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0%	3.2%	5.7%	--	--	--
4 Year Step Down (mg/kg)	0.022	0.30	0.34	--	--	--
Recovery (%)	3.2%	4% (power)	5.7%	--	--	--

Notes:
Used SWACs based on GIS and Arithmetic approaches for Remedial Reach (see Table 4-3 for SWAC values)
-- Not calculated
Percentages with no (explanation) calculated from the log-linear regression

S-5 (Includes Urban and Dam)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0%	3.2%	5.7%	6.3%	7.5%	8.9%
10 Year Step Down (mg/kg)	0.045	0.28	0.34	0.059	0.39	0.49
Recovery (%)	3.2%	4.5% (power)	5.7%	7.5%	8% (power)	8.9%

Notes:
Used Area 1 Wide SWAC (see Section 4.7.2.1)
Percentages with no (explanation) calculated from a log-linear regression

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Table 4-0c
Common Carp Fillet: Fish Projection Rate Percentages and Step Downs
Area 1, OU5 Kalamazoo River

S-2 (Includes Urban and Dam)						
	Urban Area			Dams Area		
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
MNR (%)	0.58%	2.2%	6.1%	1.6%	2.8%	3.9%
Recovery (%)	0.58%	2.2%	6.1%	1.6%	2.8%	3.9%

Notes:
Percentages with no (explanation) calculated from a log-linear regression

S-3 (Includes Urban Only)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0.58%	2.2%	6.1%	--	--	--
2 Year Step Down (mg/kg)	0.11	0.90	1.4	--	--	--
Recovery (%)	2.2%	3.5% (power)	6.1%	--	--	--

Notes:
Used SWACs based on GIS and Arithmetic approaches for Remedial Reach (see Table 4-3 for SWAC values)
-- Not calculated
Percentages with no (explanation) calculated from a log-linear regression

S-4 (Includes Urban Only)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0.58%	2.2%	6.1%	--	--	--
4 Year Step Down (mg/kg)	0.12	1.6	1.6	--	--	--
Recovery (%)	2.2%	3.5% (power)	6.1%	--	--	--

Notes:
Used SWACs based on GIS and Arithmetic approaches for Remedial Reach (see Table 4-3 for SWAC values)
-- Not calculated
Percentages with no (explanation) calculated from a log-linear regression

S-5 (Includes Urban and Dam)						
	Upper Bound	Mid	Lower Bound	Upper Bound	Mid	Lower Bound
2 Year MNR (%)	0.58%	2.2%	6.1%	1.6%	2.8%	3.9%
10 Year Step Down (mg/kg)	0.24	1.4	1.5	0.19	1.1	1.4
Recovery (%)	2.2%	4.5% (power)	6.1%	2.8%	3.5% (power)	3.9%

Notes:
Used Area 1 Wide SWAC (see Section 4.7.2.1)
Percentages with no (explanation) calculated from a log-linear regression

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Table 4-1a
Summary of Years from Initiation of Remediation to Achieve Smallmouth Bass Fillet Concentration Thresholds
Area 1, OU5 Kalamazoo River

		Fish Concentration Thresholds									
		2012 Morrow Lake Reference Concentration 0.23 mg/kg		MDCH: 2 Meals Per Month 0.11 mg/kg		Human Health Fish Consumption RBC: High End Sport Angler (HQ =1) 0.072 mg/kg		Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) 0.042 mg/kg		2006 Ceresco Reservoir Reference Concentration 0.026 mg/kg	
Remedial Alternative Scenarios		Urban	Dam	Urban	Dam	Urban	Dam	Urban	Dam	Urban	Dam
S-2	Lower Bound S-2: (MNR)	Achieved	9	9	25	17	35	26	47	34	57
	S-2: (MNR)	Achieved	18	16	47	29	65	43	87	56	106
	Upper Bound S-2: (MNR)	Achieved	151	NA	375	NA	504	NA	667	NA	813
S-3	Lower Bound S-3: Section 2-4 Hotspots (Lower Bound Step Down)	Achieved	NC	2	NC	9	NC	18	NC	26	NC
	S-3: Section 2-4 Hotspots (Mid Approximation Step Down)	Achieved	NC	10	NC	22	NC	35	NC	46	NC
	Upper Bound S-3: Section 2-4 Hotspots (Upper Bound Step Down)	Achieved	NC	19	NC	32	NC	46	NC	59	NC
S-4	Lower Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Lower Bound Step Down)	Achieved	NC	4	NC	10	NC	19	NC	27	NC
	S-4: Section 2-4 Hotspots and Section 3 Edges (Mid Approximation Step Down)	Achieved	NC	8	NC	20	NC	33	NC	44	NC
	Upper Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Upper Bound Step Down)	Achieved	NC	21	NC	34	NC	48	NC	61	NC
S-5	Lower Bound S-5: Area-wide Removal (Lower Bound Step Down)	Achieved	10	10	20	15	30	24	42	32	52
	S-5: Area-wide Removal (Mid Approximation Step Down)	Achieved	13	15	30	25	41	36	54	46	66
	Upper Bound S-5: Area-wide Removal (Upper Bound Step Down)	Achieved	29	26	56	39	74	53	96	66	115

Notes:
NA = Not Achievable under this scenario
NC = Not Calculated
RBC = Risk-Based Concentration
MDCH = Michigan Department of Community Health
mg/kg = milligrams per kilogram

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Table 4-1b
Summary of Years from Initiation of Remediation to Achieve Smallmouth Bass Young of Year Whole Body Concentration Thresholds
Area 1, OU5 Kalamazoo River

		Fish Concentration Thresholds					
		Mink RBC 0.60 mg/kg		2006 Morrow Lake Reference Concentration 0.34 mg/kg		2006 Ceresco Reservoir Reference Concentration 0.12 mg/kg	
	Remedial Alternative Scenarios	Urban	Dam	Urban	Dam	Urban	Dam
S-2	Lower Bound S-2: (MNR)	1	5	10	10	25	18
	S-2: (MNR)	4	7	20	13	49	24
	Upper Bound S-2: (MNR)	NA	9	NA	16	NA	30
S-3	Lower Bound S-3: Section 2-4 Hotspots (Lower Bound Step Down)	Achieved	NC	2	NC	13	NC
	S-3: Section 2-4 Hotspots (Mid Approximation Step Down)	2	NC	10	NC	35	NC
	Upper Bound S-3: Section 2-4 Hotspots (Upper Bound Step Down)	7	NC	23	NC	52	NC
S-4	Lower Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Lower Bound Step Down)	Achieved	NC	4	NC	13	NC
	S-4: Section 2-4 Hotspots and Section 3 Edges (Mid Approximation Step Down)	4	NC	4	NC	28	NC
	Upper Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Upper Bound Step Down)	9	NC	25	NC	54	NC
S-5	Lower Bound S-5: Area-wide Removal (Lower Bound Step Down)	Achieved	10	10	10	19	18
	S-5: Area-wide Removal (Mid Approximation Step Down)	10	10	11	15	33	27
	Upper Bound S-5: Area-wide Removal (Upper Bound Step Down)	14	15	30	21	59	32

Notes:
NA = Not Achievable under this scenario
NC = Not Calculated
RBC = Risk-Based Concentration
MDCH = Michigan Department of Community Health
mg/kg = milligrams per kilogram

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Table 4-1c
Summary of Years From Initiation of Remediation to Achieve Common Carp Fillet Concentration Thresholds
Area 1, OU5 Kalamazoo River

		Fish Concentration Thresholds									
		2012 Morrow Lake Reference Concentration 0.29 mg/kg		2006 Ceresco Reservoir Reference Concentration 0.13 mg/kg		MDCH: 2 Meals Per Month 0.11 mg/kg		Human Health Fish Consumption RBC: High End Sport Angler (HQ =1) 0.072 mg/kg		Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) 0.042 mg/kg	
	Remedial Alternative Scenarios	Urban	Dam	Urban	Dam	Urban	Dam	Urban	Dam	Urban	Dam
S-2	Lower Bound S-2: (MNR)	35	53	45	71	48	75	54	85	61	98
	S-2: (MNR)	110	80	143	106	150	111	169	127	192	145
	Upper Bound S-2: (MNR)	447	144	584	193	612	203	684	229	775	261
S-3	Lower Bound S-3: Section 2-4 Hotspots (Lower Bound Step Down)	27	NC	37	NC	40	NC	46	NC	53	NC
	S-3: Section 2-4 Hotspots (Mid Approximation Step Down)	66	NC	88	NC	92	NC	105	NC	120	NC
	Upper Bound S-3: Section 2-4 Hotspots (Upper Bound Step Down)	112	NC	145	NC	151	NC	170	NC	192	NC
S-4	Lower Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Lower Bound Step Down)	28	NC	38	NC	44	NC	47	NC	54	NC
	S-4: Section 2-4 Hotspots and Section 3 Edges (Mid Approximation Step Down)	60	NC	82	NC	87	NC	100	NC	115	NC
	Upper Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Upper Bound Step Down)	113	NC	147	NC	153	NC	172	NC	194	NC
S-5	Lower Bound S-5: Area-wide Removal (Lower Bound Step Down)	33	46	44	64	46	67	52	78	60	90
	S-5: Area-wide Removal (Mid Approximation Step Down)	55	61	72	83	75	87	85	100	97	115
	Upper Bound S-5: Area-wide Removal (Upper Bound Step Down)	118	87	151	114	158	119	176	135	199	153

Notes:
NA = Not Achievable under this scenario
NC = Not Calculated
RBC = Risk-Based Concentration
MDCH = Michigan Department of Community Health
mg/kg = milligrams per kilogram

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Table 4-3
Summary of SWAC bounds for Remedial Alternatives S-3 and S-4
Area 1, OU5 Kalamazoo River

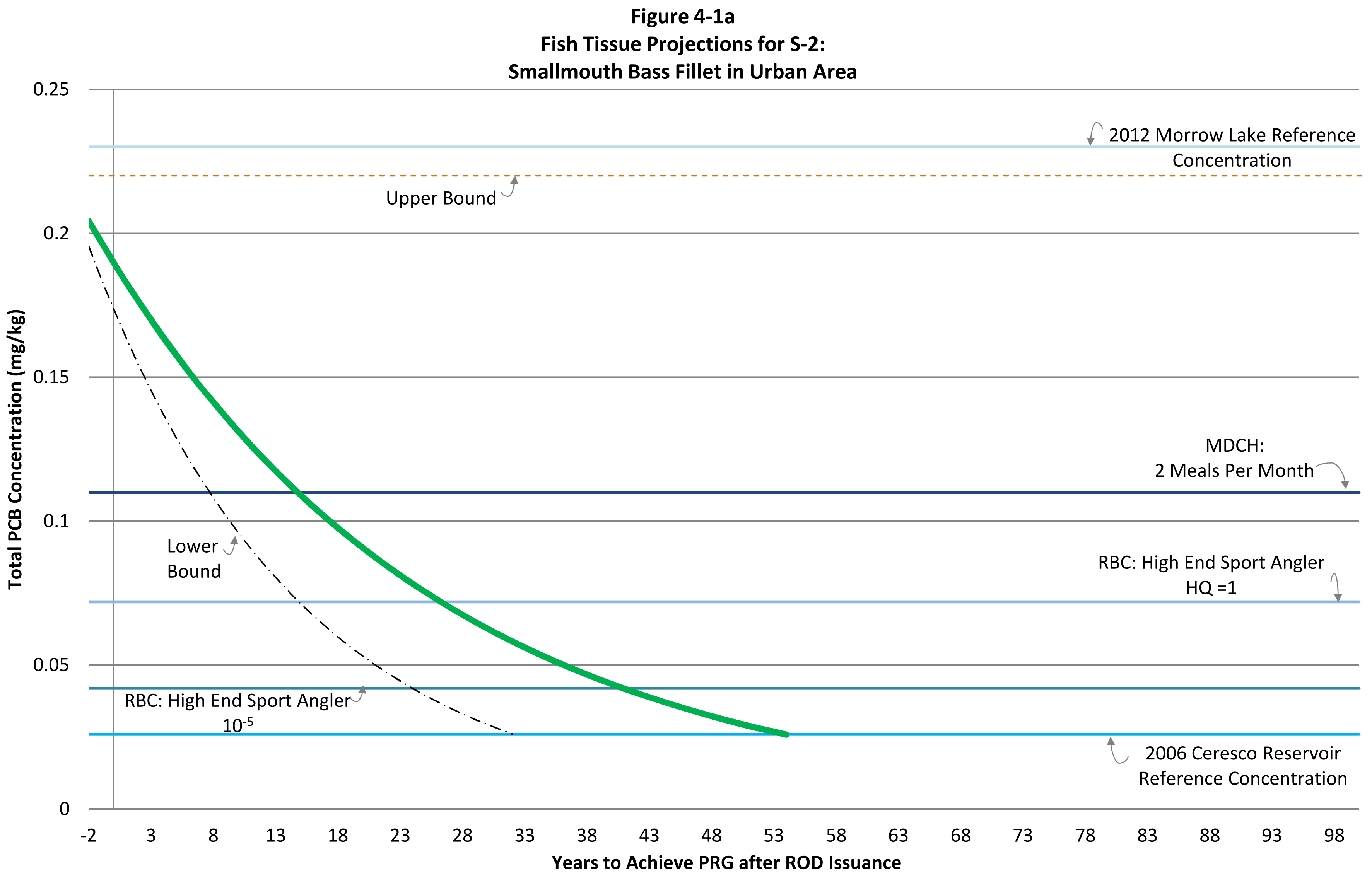
Alternative S-3	**Remedial Reach[a] SWACs (mg/kg)**											
	Interval 1			**Interval 2**			**Inteval 3**			**Combined Intervals**		
	LCL	**Best Est.(S-3C)**	**UCL**	**LCL**	**Best Est.(S-3C)**	**UCL**	**LCL**	**Best Est.(S-3C)**	**UCL**	**LCL**	**Best Est.(S-3C)**	**UCL**
Pre Remediation	0.49	1.76	2.33	0.20	2.35	4.73	0.18	2.66	2.91	0.87	2.21	2.96
Post Remediation	0.35	1.09	1.06	0.06	1.12	3.07	0.00	1.00	1.27	0.39	1.07	1.73

Alternative S-4	**Remedial Reach SWACs (mg/kg)**											
	Interval 1			**Interval 2**			**Inteval 3**			**Combined Intervals**		
	LCL	**Best Est. (S-4F)**	**UCL**	**LCL**	**Best Est. (S-4F)**	**UCL**	**LCL**	**Best Est. (S-4F)**	**UCL**	**LCL**	**Best Est. (S-4F)**	**UCL**
Pre Remediation	0.49	1.76	2.23	0.30	2.35	3.32	0.25	2.66[d]	2.53	0.86	2.21	2.31
Post Remediation	0.34	0.60	0.90	0.43[c]	0.72	0.79	0.00	0.56	0.81	0.50	0.63	0.71

Notes:
LCL - lower confidence limit
UCL - upper confidence limit
SWAC - Surface area weighted average concentration
IPWCs - Interval participation weighted concentrations
a. The Remedial Reach extends approximately 3 miles, from RM72.4 (upstream of KPT 19) to RM69.4 (downstream of S-IM1) and includes hot spots KPT-19, KPT-20, KRT-4, KRT-5, and S-IM1.
b. Best Estimate corresponds to calculation methods S-3C and S-4F, which are the most representative of site conditions based on the available data by limiting the post-remediation "credit" for removal to the actual footprint of excavation (rather than whole stream tubes), and consider all of the available sediment data within a hot spot area.
c. Post-remediation SWACs do not include sample variability from hotspots and edges. LCL and UCL values calculated solely on sample variability of the remaining reach concentrations. For interval 2, this results in a slightly higher post-remediation LCL than the pre-remediation LCL.
d. Best estimate in this scenario is slightly above the UCL calculated. The difference between these two methods is that one weights each hot spot area separately and the other weights the aggregate average hot spot concentration. The UCL is based on the latter, which has lower variability.

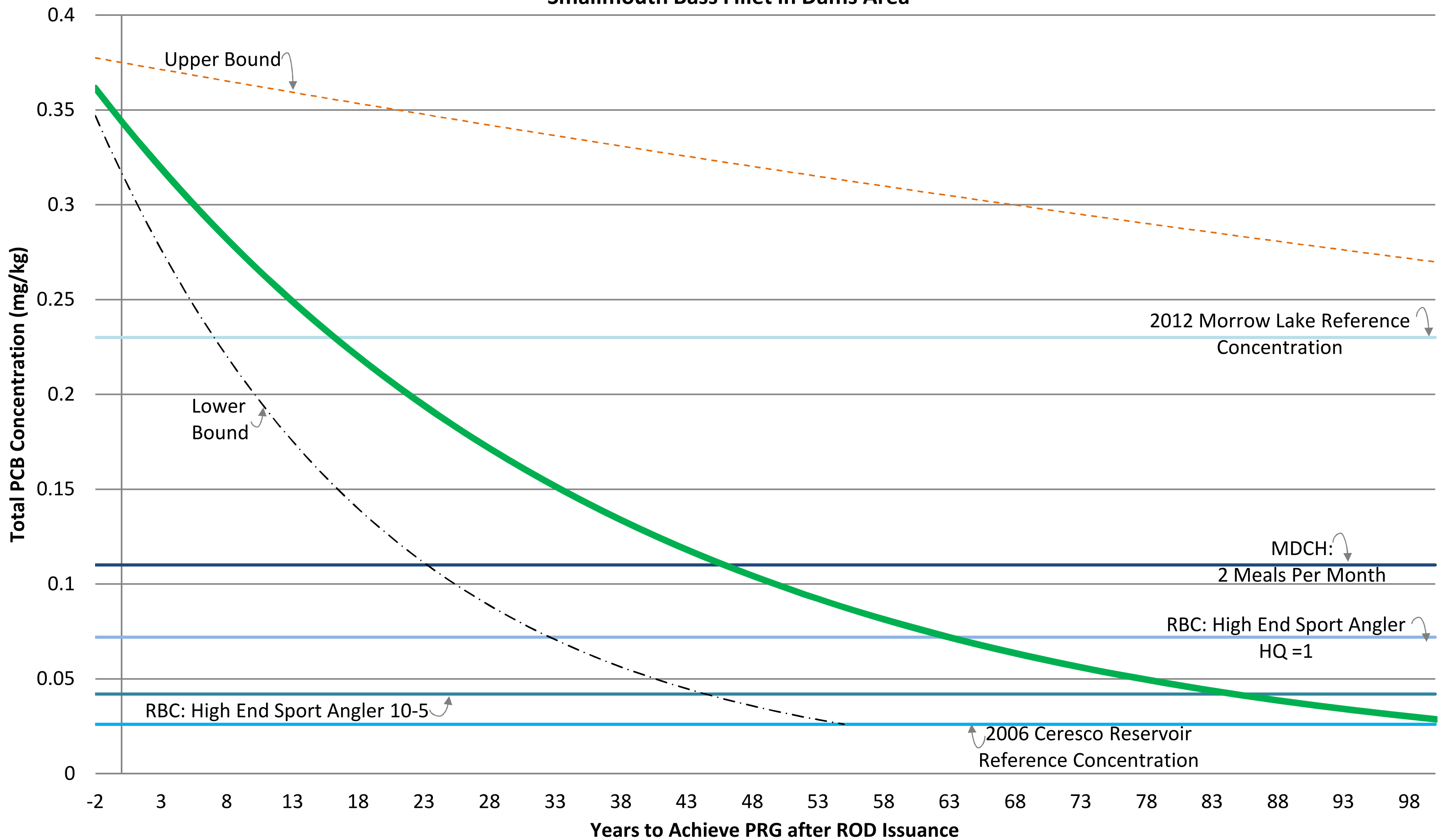
Interval 1 = 0" to 6"
Interval 2 = 6" to 12"
Interval 3 = 12" to 24"

Prepared by/Date: MTP 12/18/2013
Checked by/Date: CED 12/18/2013



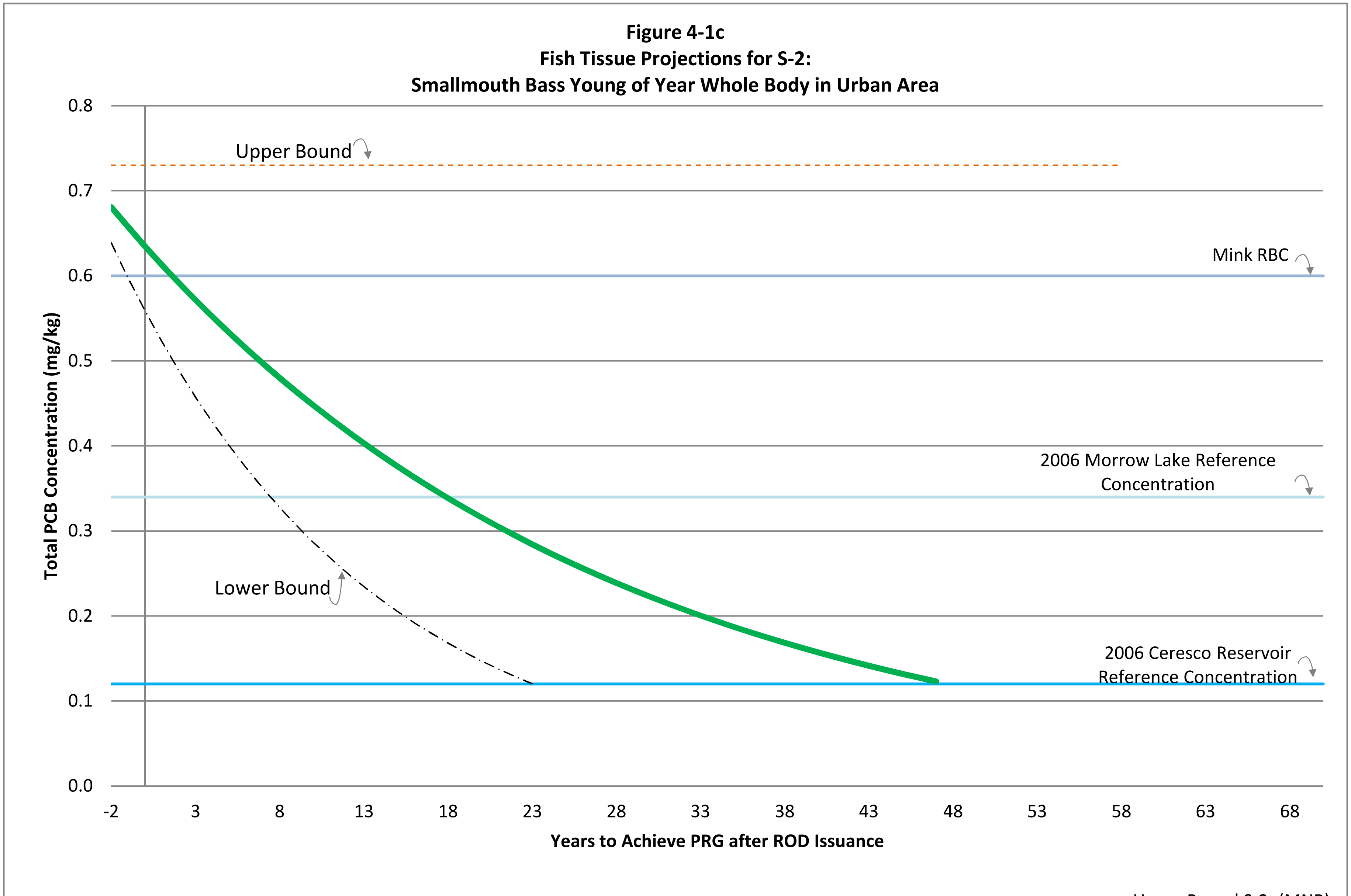
2012 Morrow Lake Reference Concentration = 0.23 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ = 1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-4}) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) = 0.042 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.026 mg/kg
Refer to Table I-1.1 for definition of segments

Figure 4-1b
Fish Tissue Projections for S-2:
Smallmouth Bass Fillet in Dams Area



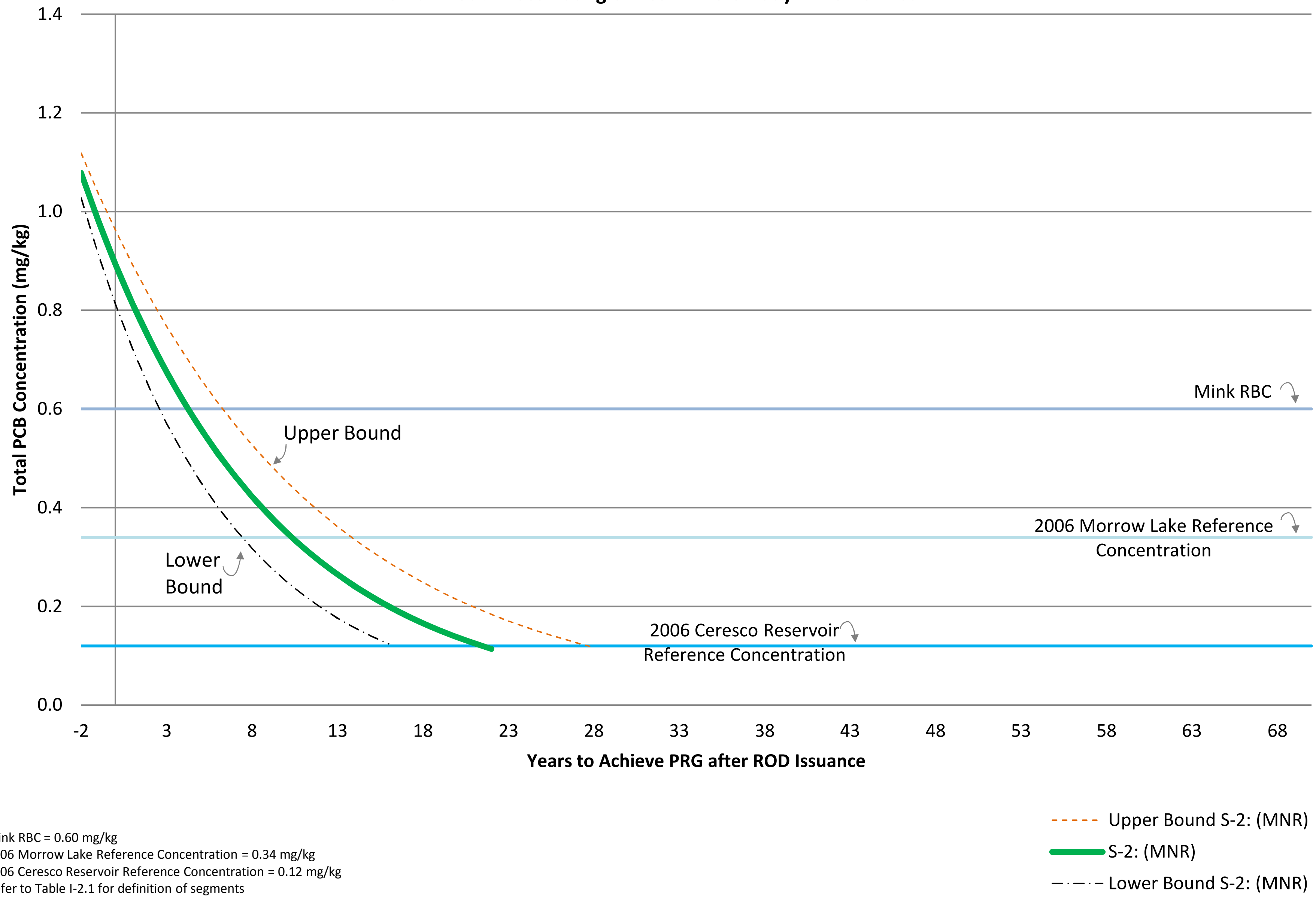
2012 Morrow Lake Reference Concentration = 0.23 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ = 1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-4}) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) = 0.042 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.026 mg/kg
Refer to Table I-1.1 for definition of segments

Upper Bound S-2: (MNR)
S-2: (MNR)
Lower Bound S-2: (MNR)

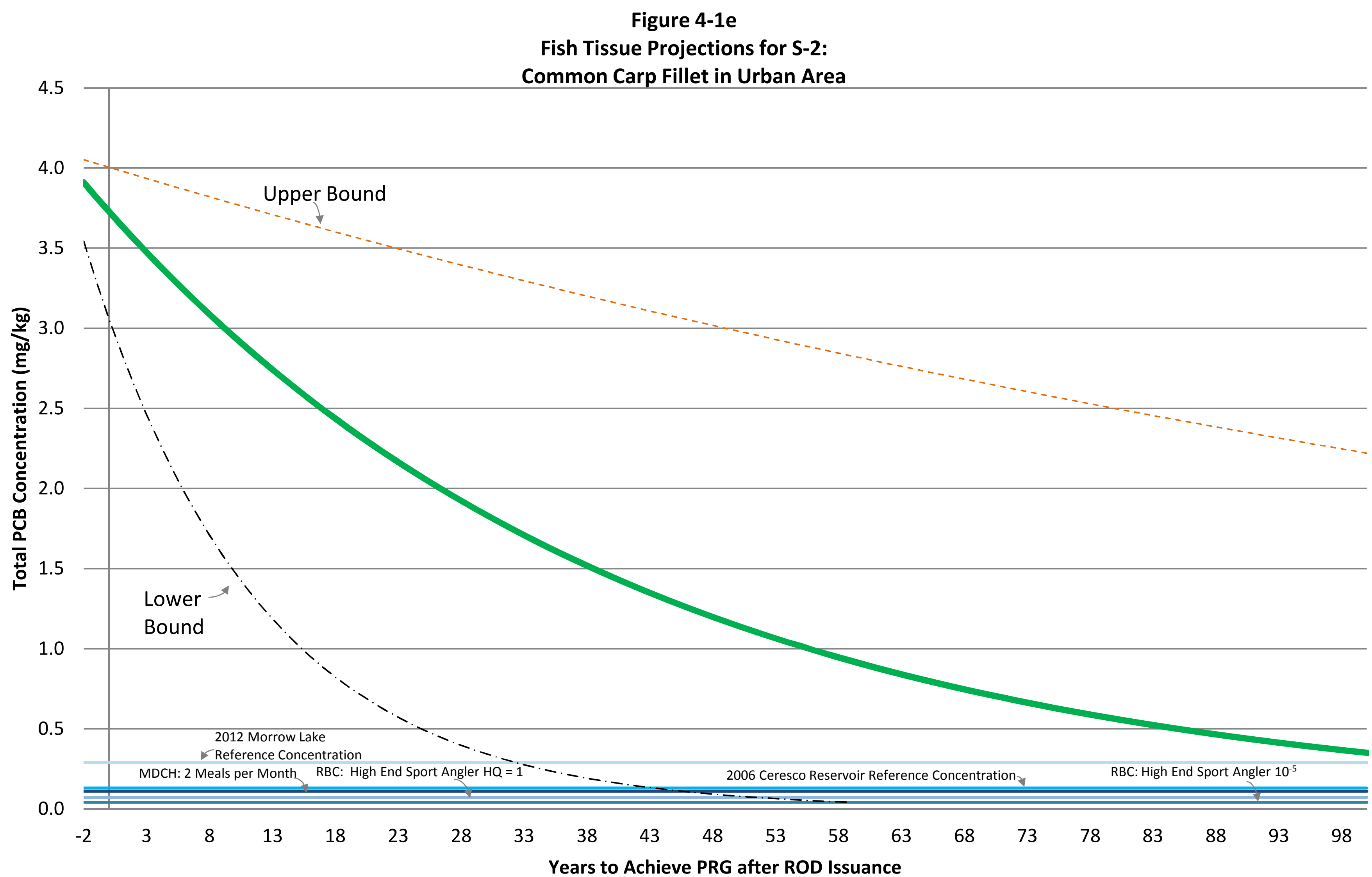


Mink RBC = 0.60 mg/kg
2006 Morrow Lake Reference Concentration = 0.34 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.12 mg/kg
Refer to Table I-2.1 for definition of segments

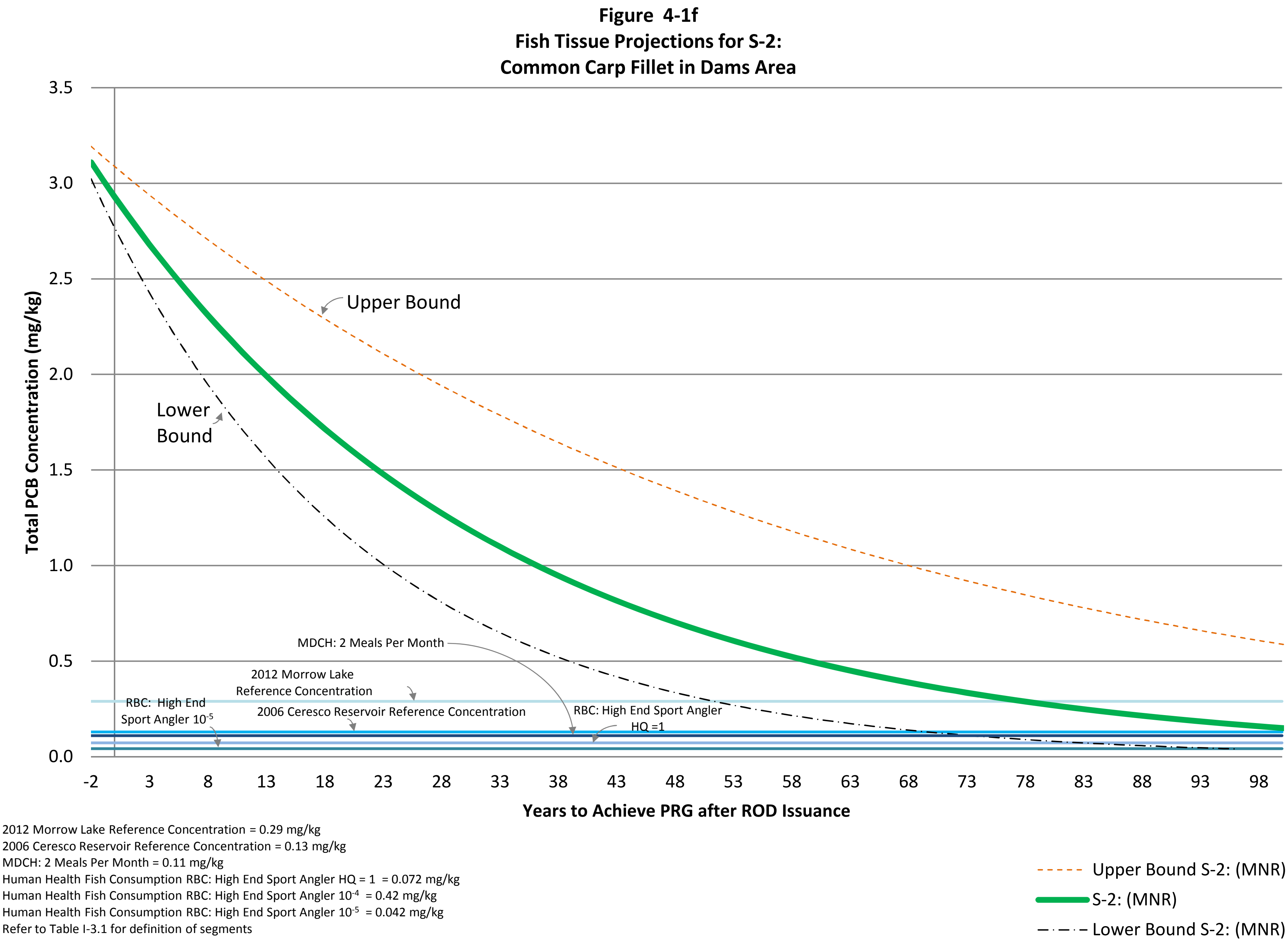
Figure 4-1d
Fish Tissue Projections for S-2:
Smallmouth Bass Young of Year Whole Body in Dams Area



Mink RBC = 0.60 mg/kg
2006 Morrow Lake Reference Concentration = 0.34 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.12 mg/kg
Refer to Table I-2.1 for definition of segments



2012 Morrow Lake Reference Concentration = 0.29 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.13 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler HQ =1 = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler 10^{-4} = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler 10^{-5} = 0.042 mg/kg
Refer to Table I-3.1 for definition of segments



2012 Morrow Lake Reference Concentration = 0.29 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.13 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler HQ = 1 = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler 10^{-4} = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler 10^{-5} = 0.042 mg/kg
Refer to Table I-3.1 for definition of segments

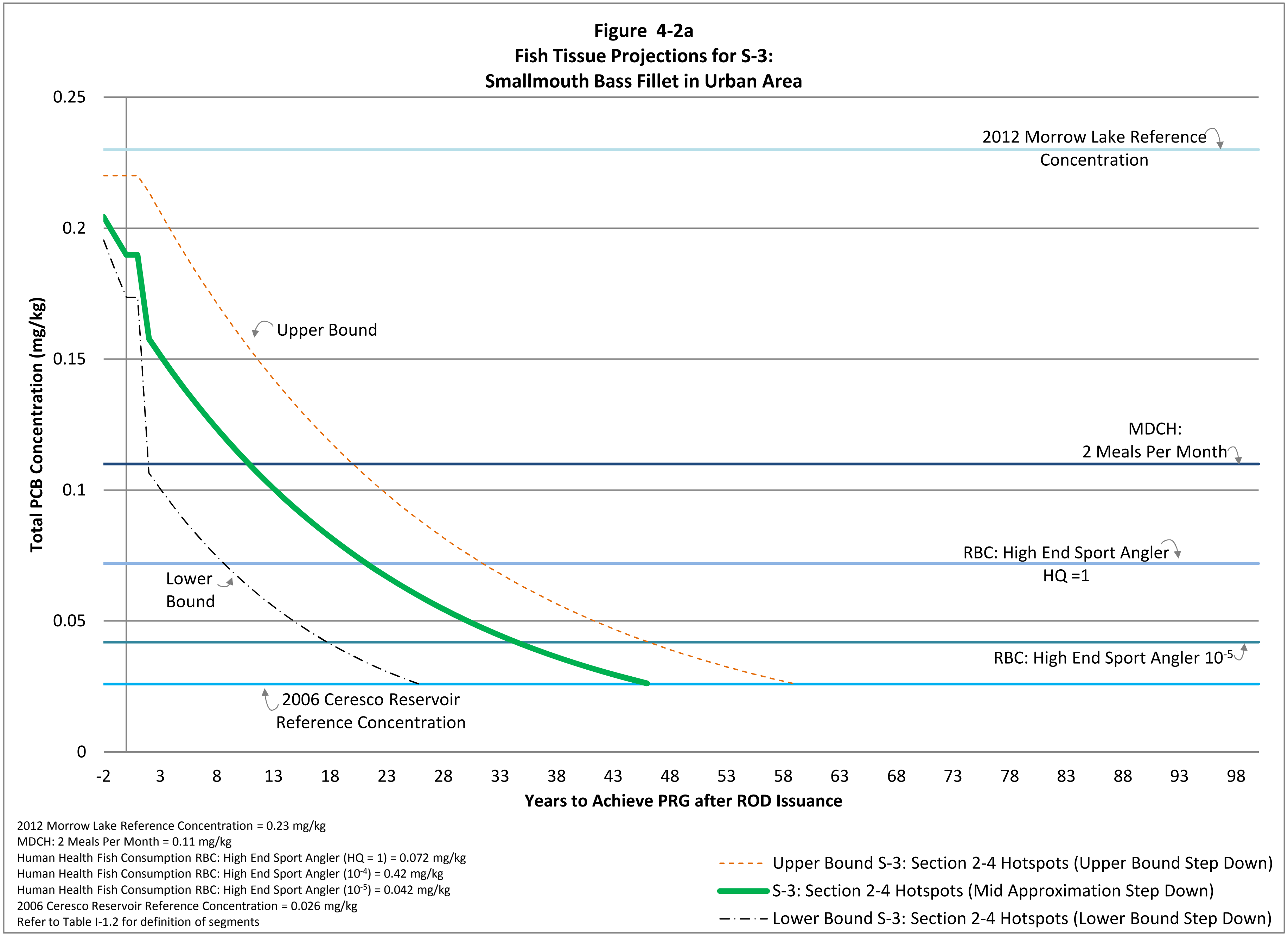


Figure 4-2a
Fish Tissue Projections for S-3:
Smallmouth Bass Fillet in Urban Area
Total PCB Concentration (mg/kg)
0.25
0.2
0.15
0.1
0.05
0
-2
3
8
13
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
98
Years to Achieve PRG after ROD Issuance
2012 Morrow Lake Reference Concentration
Upper Bound
MDCH: 2 Meals Per Month
RBC: High End Sport Angler HQ =1
Lower Bound
RBC: High End Sport Angler 10-5
2006 Ceresco Reservoir Reference Concentration
2012 Morrow Lake Reference Concentration = 0.23 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ = 1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10-4) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10-5) = 0.042 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.026 mg/kg
Refer to Table I-1.2 for definition of segments
Upper Bound S-3: Section 2-4 Hotspots (Upper Bound Step Down)
S-3: Section 2-4 Hotspots (Mid Approximation Step Down)
Lower Bound S-3: Section 2-4 Hotspots (Lower Bound Step Down)

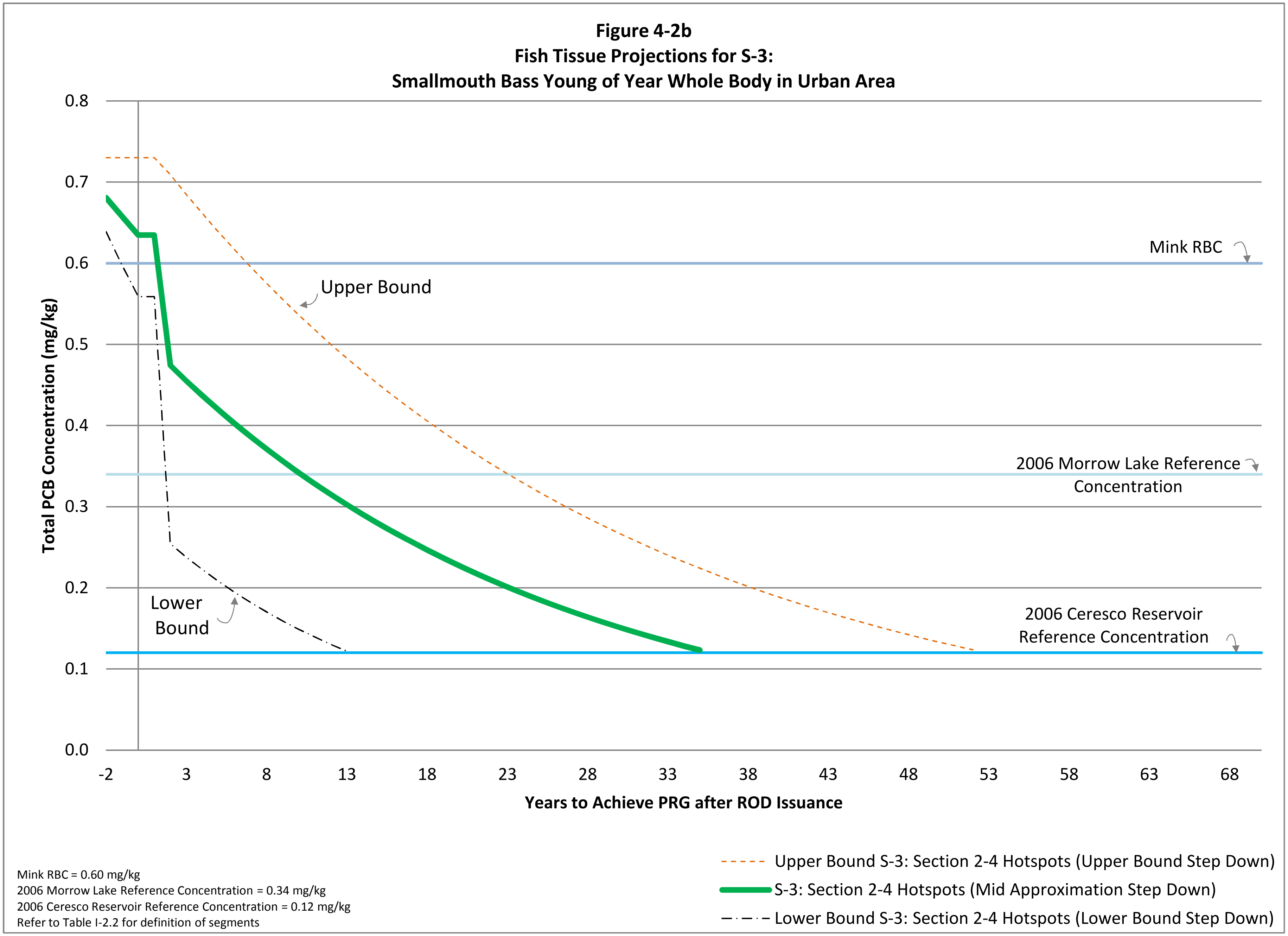
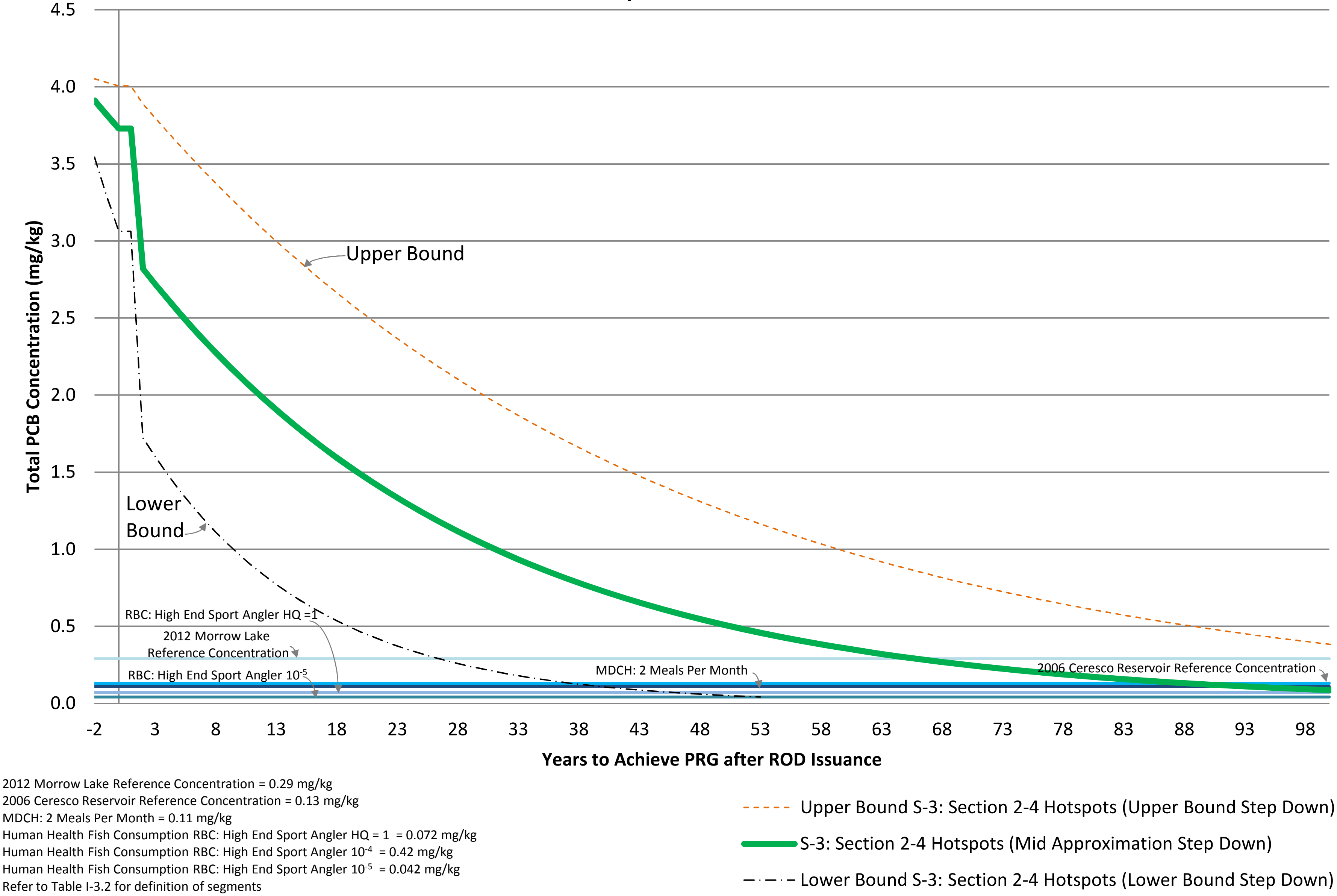


Figure 4-2b
Fish Tissue Projections for S-3:
Smallmouth Bass Young of Year Whole Body in Urban Area
Total PCB Concentration (mg/kg)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-2
3
8
13
18
23
28
33
38
43
48
53
58
63
68
Years to Achieve PRG after ROD Issuance
Mink RBC
Upper Bound
2006 Morrow Lake Reference Concentration
Lower Bound
2006 Ceresco Reservoir Reference Concentration
Upper Bound S-3: Section 2-4 Hotspots (Upper Bound Step Down)
S-3: Section 2-4 Hotspots (Mid Approximation Step Down)
Lower Bound S-3: Section 2-4 Hotspots (Lower Bound Step Down)
Mink RBC = 0.60 mg/kg
2006 Morrow Lake Reference Concentration = 0.34 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.12 mg/kg
Refer to Table I-2.2 for definition of segments

Figure 4-2c
Fish Tissue Projections for S-3:
Common Carp Fillet in Urban Area



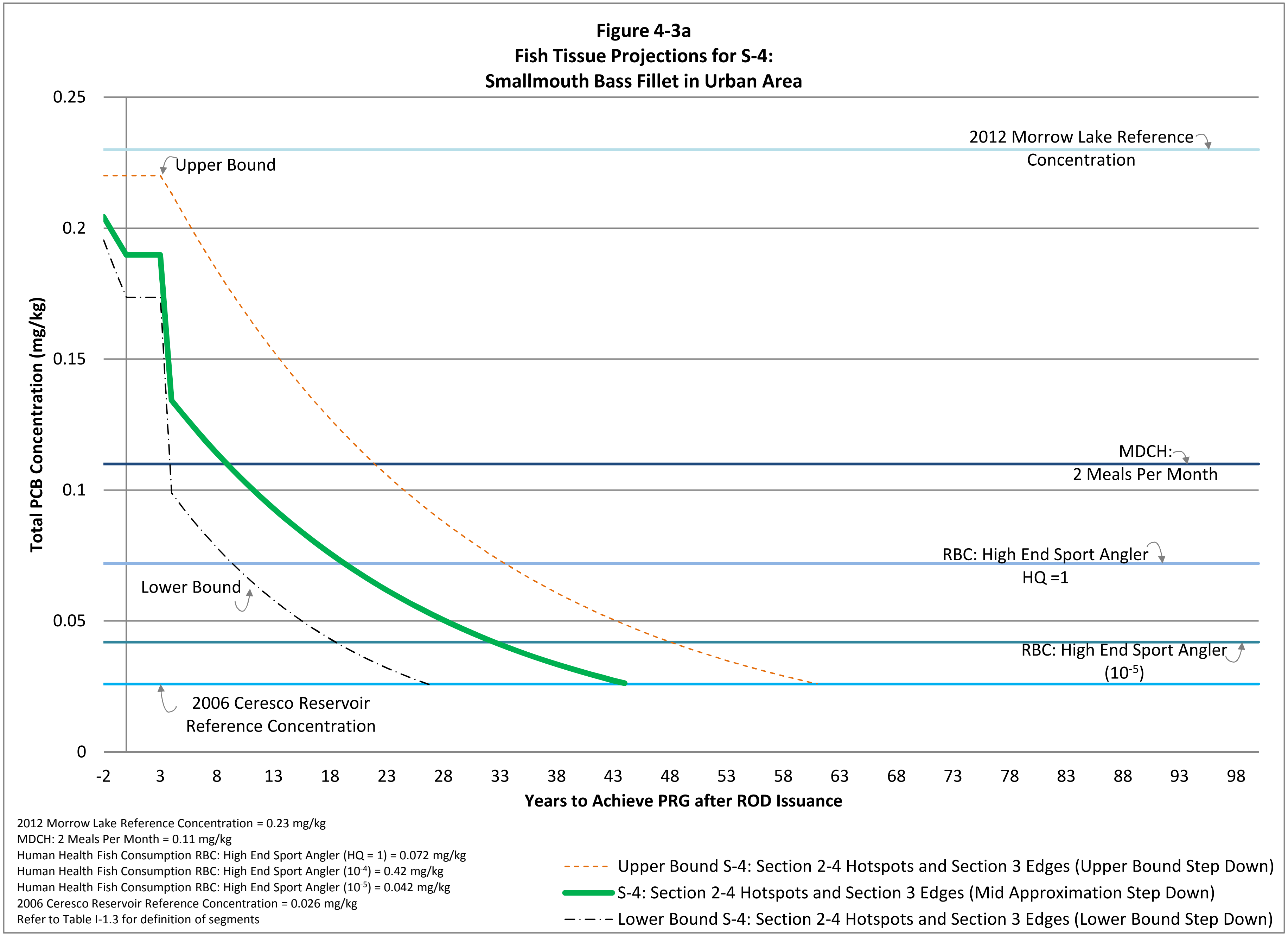
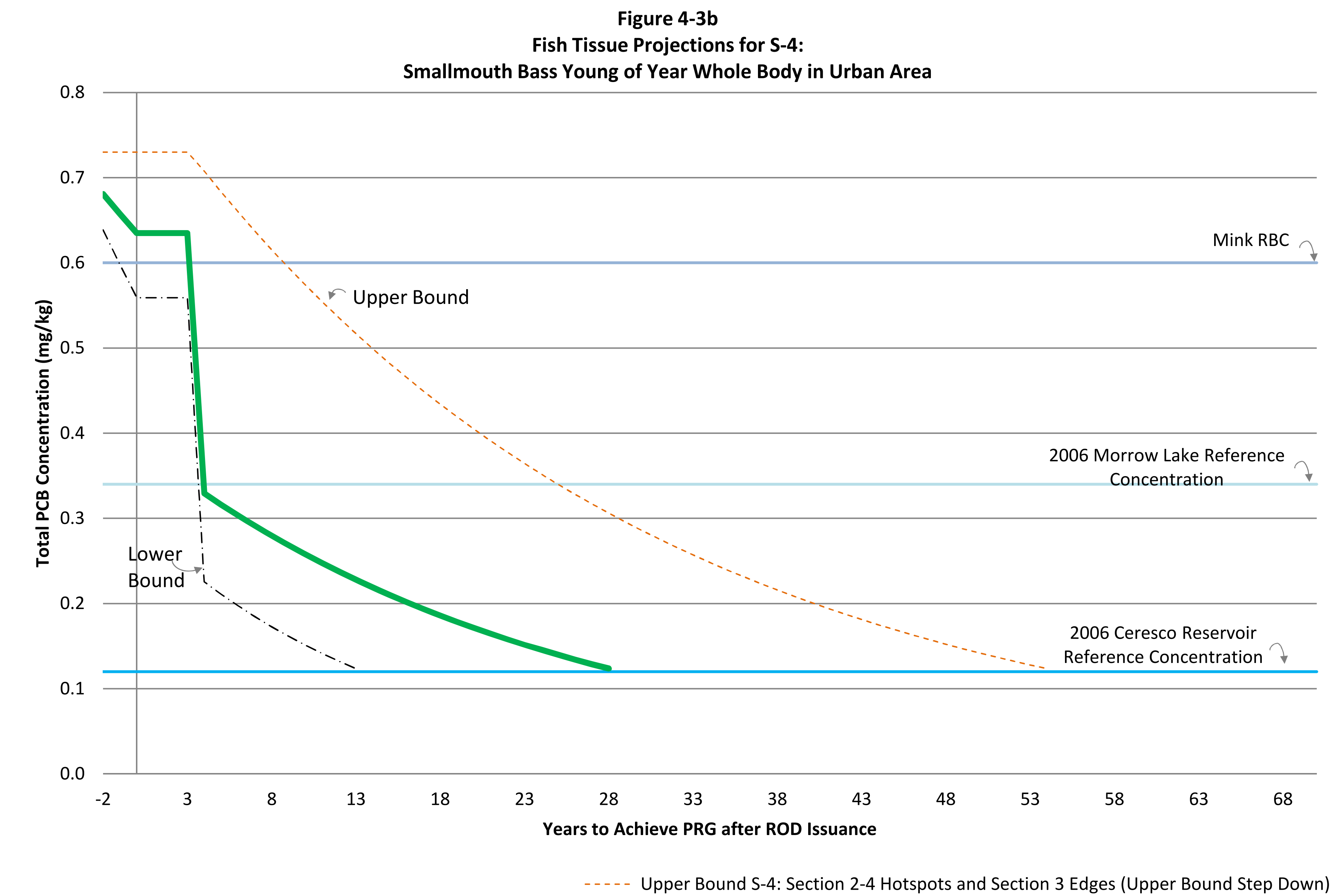


Figure 4-3a
Fish Tissue Projections for S-4:
Smallmouth Bass Fillet in Urban Area
Total PCB Concentration (mg/kg)
0.25
0.2
0.15
0.1
0.05
0
-2
3
8
13
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
98
Years to Achieve PRG after ROD Issuance
2012 Morrow Lake Reference Concentration
Upper Bound
MDCH: 2 Meals Per Month
RBC: High End Sport Angler HQ =1
Lower Bound
RBC: High End Sport Angler (10^{-5})
2006 Ceresco Reservoir Reference Concentration
2012 Morrow Lake Reference Concentration = 0.23 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ = 1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-4}) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) = 0.042 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.026 mg/kg
Refer to Table I-1.3 for definition of segments
Upper Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Upper Bound Step Down)
S-4: Section 2-4 Hotspots and Section 3 Edges (Mid Approximation Step Down)
Lower Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Lower Bound Step Down)



Mink RBC = 0.60 mg/kg
2006 Morrow Lake Reference Concentration = 0.34 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.12 mg/kg
Refer to Table I-2.3 for definition of segments

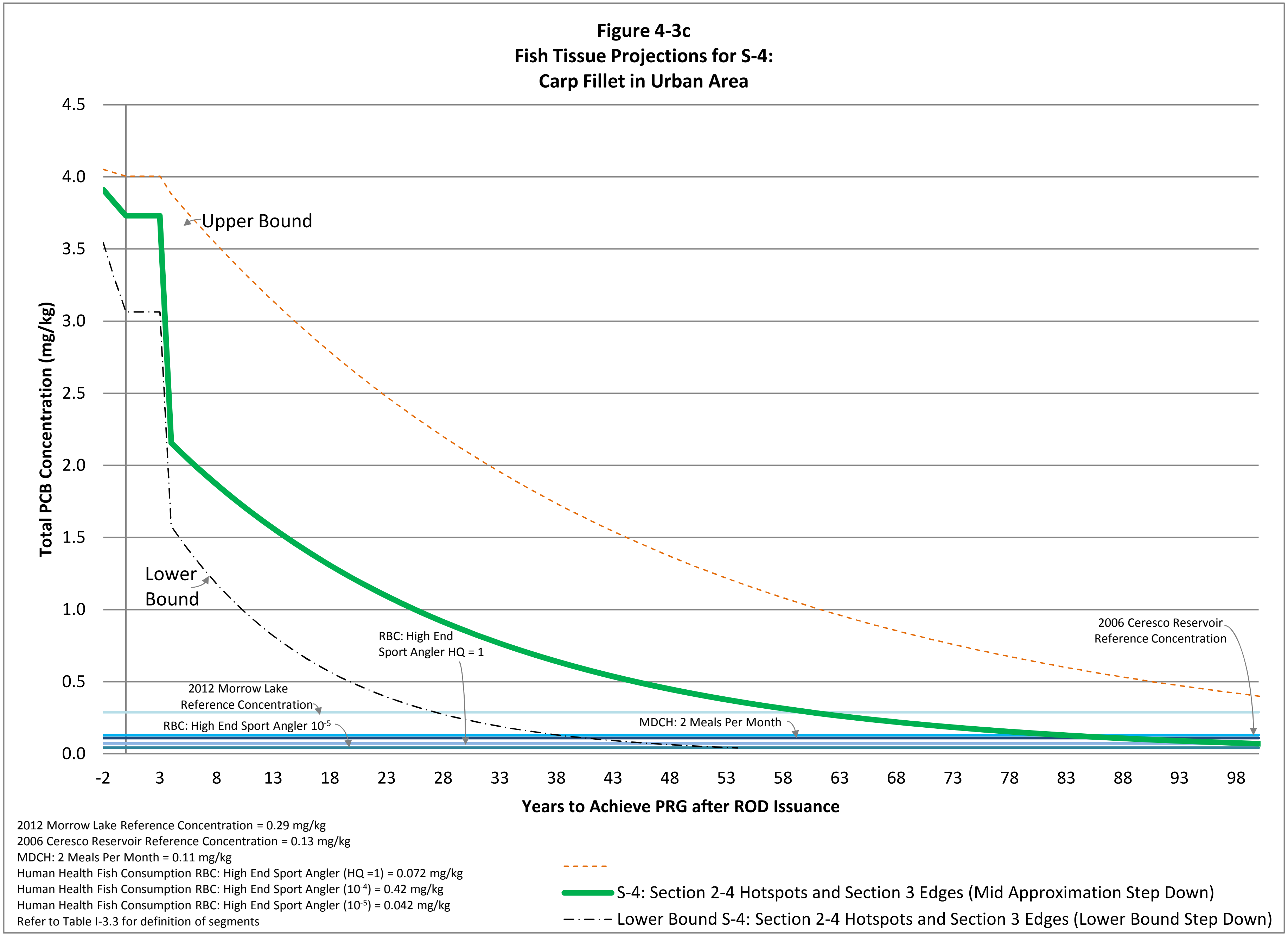
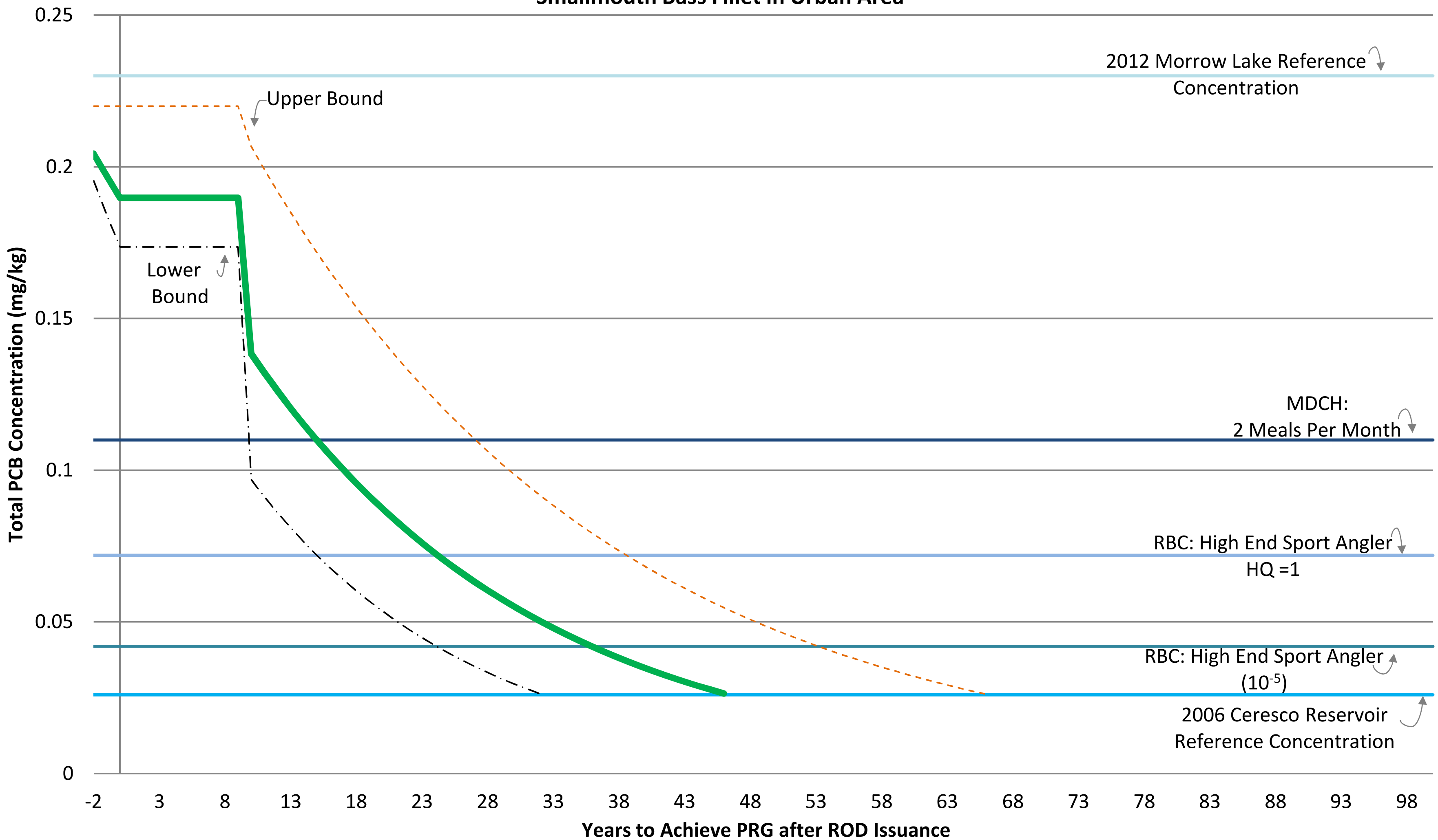


Figure 4-3c
Fish Tissue Projections for S-4:
Carp Fillet in Urban Area
Total PCB Concentration (mg/kg)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Upper Bound
Lower Bound
RBC: High End Sport Angler HQ = 1
2006 Ceresco Reservoir Reference Concentration
2012 Morrow Lake Reference Concentration
RBC: High End Sport Angler 10-5
MDCH: 2 Meals Per Month
-2
3
8
13
18
23
28
33
38
43
48
53
58
63
68
73
78
83
88
93
98
Years to Achieve PRG after ROD Issuance
2012 Morrow Lake Reference Concentration = 0.29 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.13 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ =1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10-4) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10-5) = 0.042 mg/kg
Refer to Table I-3.3 for definition of segments
S-4: Section 2-4 Hotspots and Section 3 Edges (Mid Approximation Step Down)
Lower Bound S-4: Section 2-4 Hotspots and Section 3 Edges (Lower Bound Step Down)

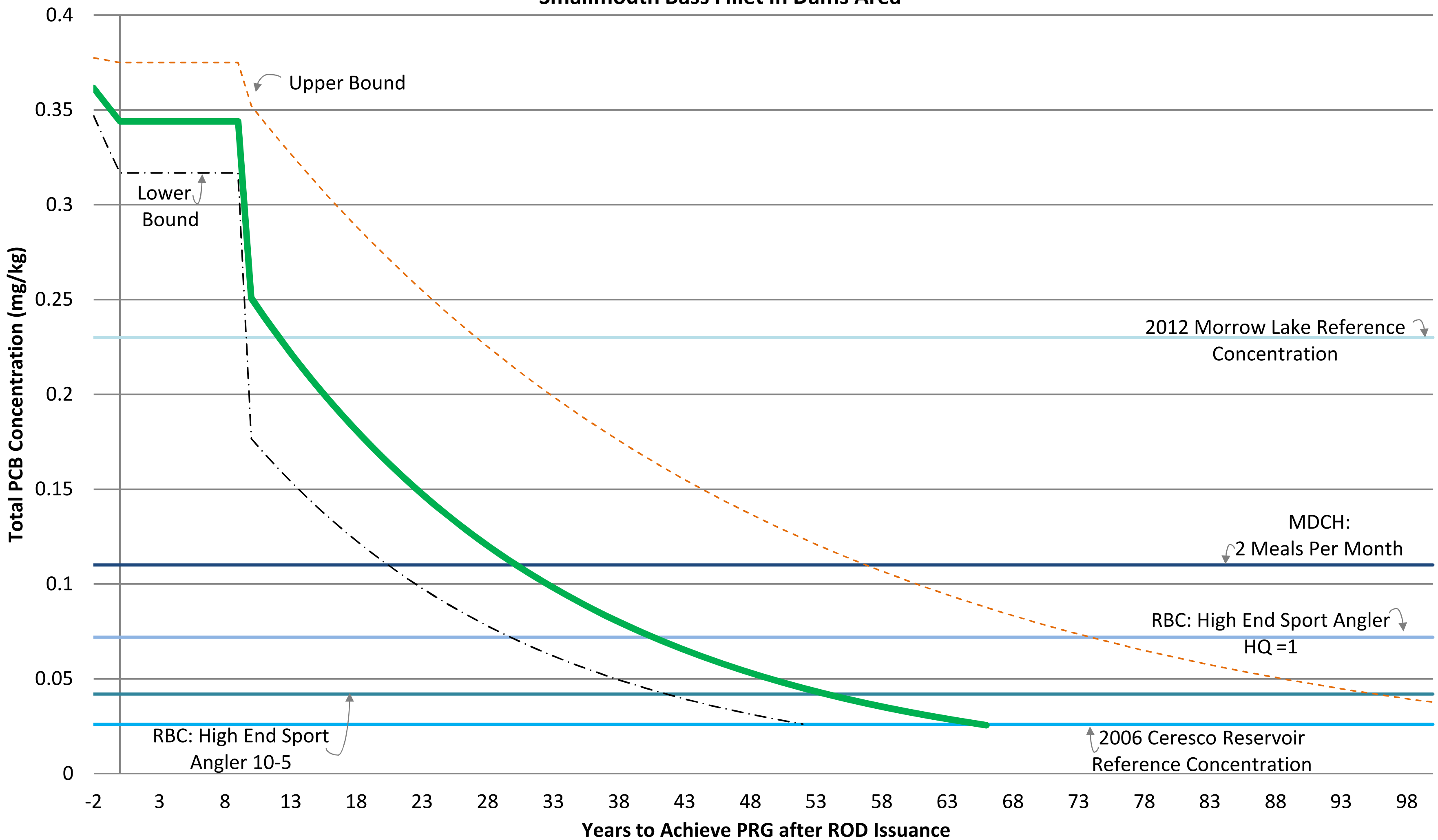
Figure 4-4a
Fish Tissue Projections for S-5:
Smallmouth Bass Fillet in Urban Area



2012 Morrow Lake Reference Concentration = 0.23 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ = 1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-4}) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) = 0.042 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.026 mg/kg
Refer to Table I-1.4 for definition of segments

Upper Bound S-5: Area-wide Removal (Upper Bound Step Down)
S-5: Area-wide Removal (Mid Approximation Step Down)
Lower Bound S-5: Area-wide Removal (Lower Bound Step Down)

Figure 4-4b
Fish Tissue Projections for S-5:
Smallmouth Bass Fillet in Dams Area



2012 Morrow Lake Reference Concentration = 0.23 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ = 1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-4}) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) = 0.042 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.026 mg/kg
Refer to Table I-1.4 for definition of segments

Upper Bound S-5: Area-wide Removal (Upper Bound Step Down)
S-5: Area-wide Removal (Mid Approximation Step Down)
Lower Bound S-5: Area-wide Removal (Lower Bound Step Down)

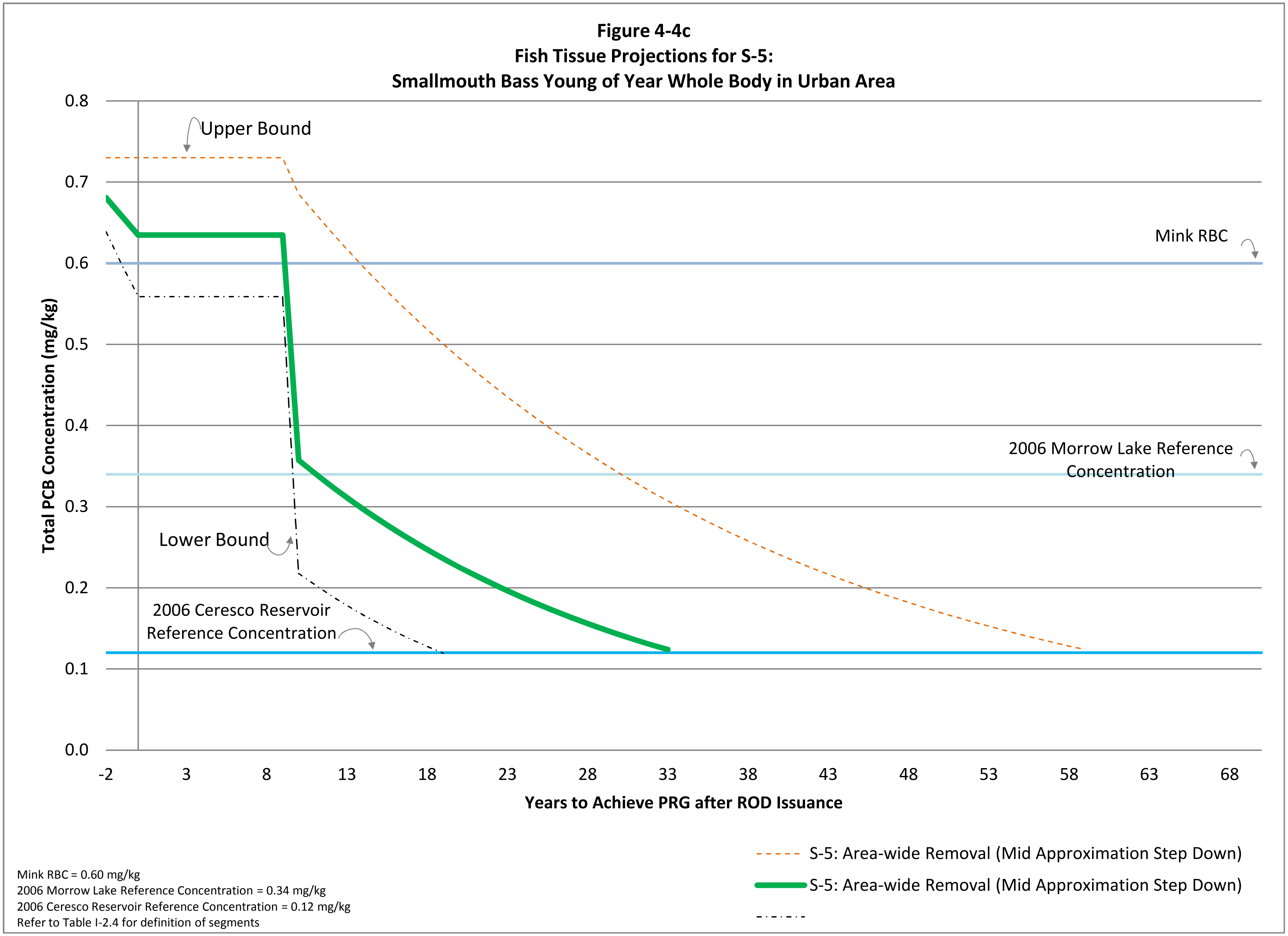
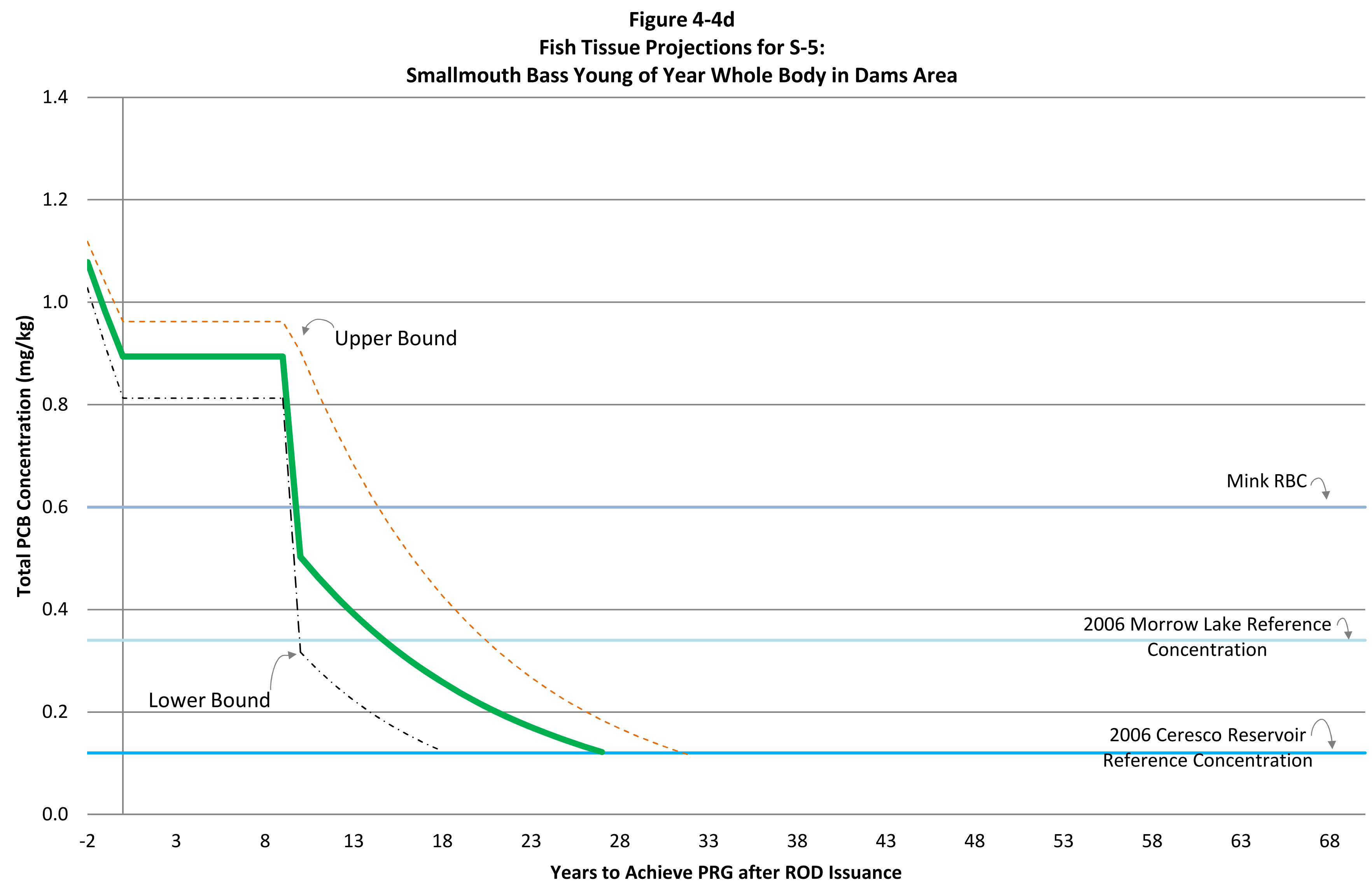
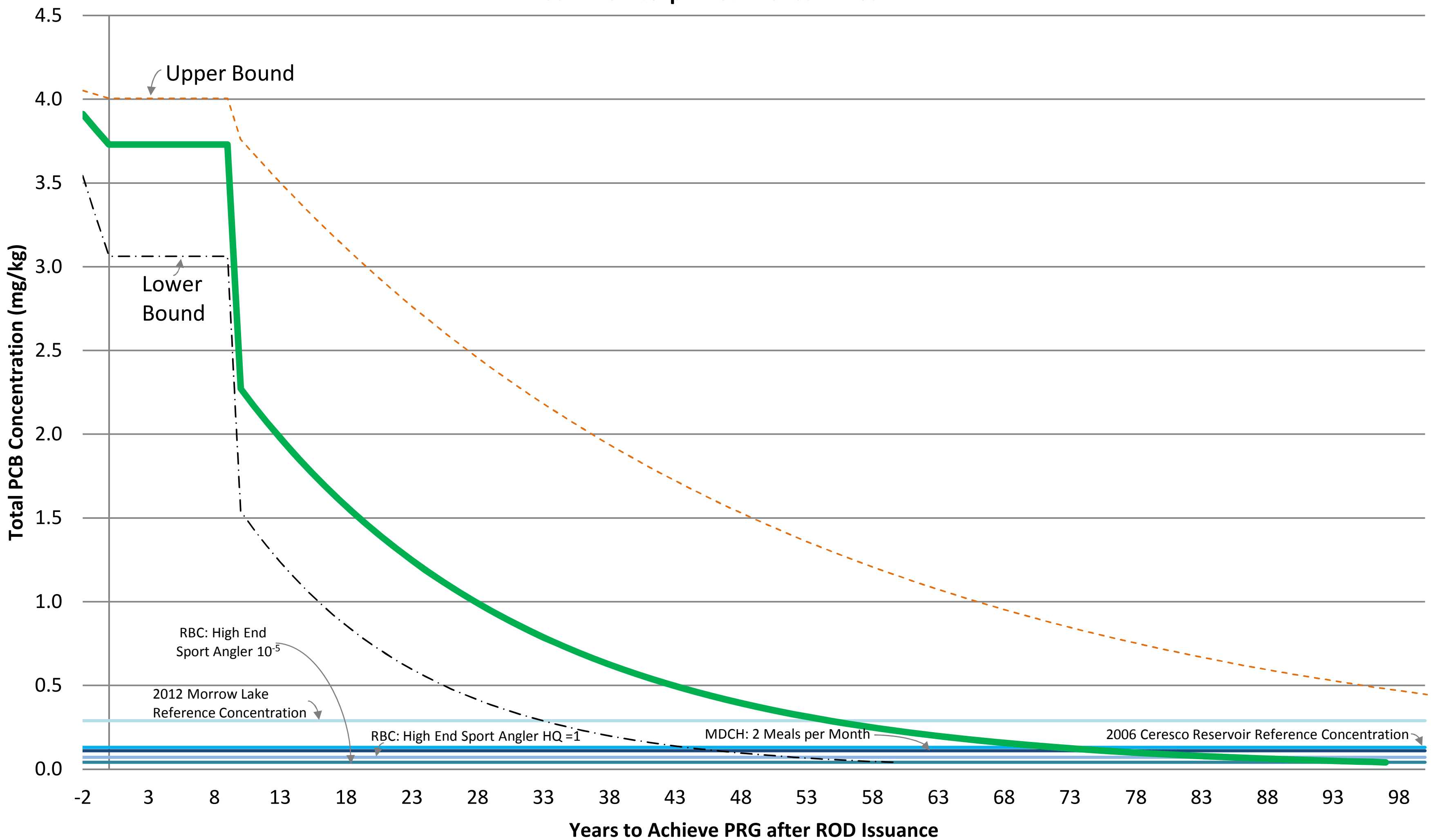


Figure 4-4c
Fish Tissue Projections for S-5:
Smallmouth Bass Young of Year Whole Body in Urban Area
Upper Bound
Mink RBC
2006 Morrow Lake Reference Concentration
Lower Bound
2006 Ceresco Reservoir Reference Concentration
Total PCB Concentration (mg/kg)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-2
3
8
13
18
23
28
33
38
43
48
53
58
63
68
Years to Achieve PRG after ROD Issuance
S-5: Area-wide Removal (Mid Approximation Step Down)
S-5: Area-wide Removal (Mid Approximation Step Down)
Mink RBC = 0.60 mg/kg
2006 Morrow Lake Reference Concentration = 0.34 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.12 mg/kg
Refer to Table I-2.4 for definition of segments



Mink RBC = 0.60 mg/kg
2006 Morrow Lake Reference Concentration = 0.34 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.12 mg/kg
Refer to Table I-2.4 for definition of segments

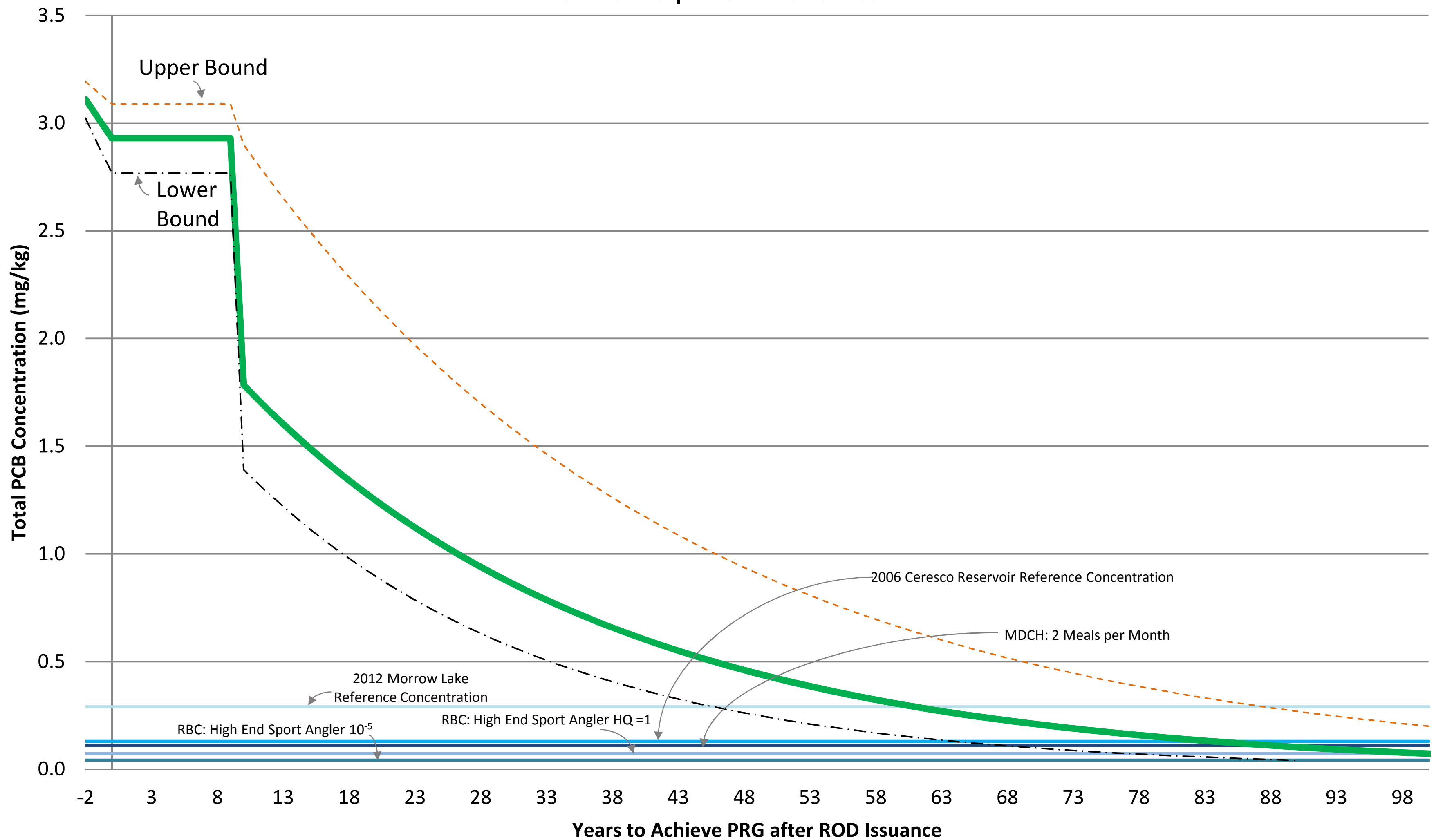
Figure 4-4e
Fish Tissue Projections for S-5:
Common Carp Fillet in Urban Area



2012 Morrow Lake Reference Concentration = 0.29 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.13 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ =1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-4}) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) = 0.042 mg/kg
Refer to Table I-3.4 for definition of segments

Upper Bound S-5: Area-wide Removal (Upper Bound Step Down)
S-5: Area-wide Removal (Mid Approximation Step Down)
Lower Bound S-5: Area-wide Removal (Lower Bound Step Down)

Figure 4-4f
Fish Tissue Projections for S-5:
Common Carp Fillet in Dams Area



2012 Morrow Lake Reference Concentration = 0.29 mg/kg
2006 Ceresco Reservoir Reference Concentration = 0.13 mg/kg
MDCH: 2 Meals Per Month = 0.11 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (HQ =1) = 0.072 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-4}) = 0.42 mg/kg
Human Health Fish Consumption RBC: High End Sport Angler (10^{-5}) = 0.042 mg/kg
Refer to Table I-3.4 for definition of segments

Upper Bound S-5: Area-wide Removal (Upper Bound Step Down)
S-5: Area-wide Removal (Mid Approximation Step Down)
Lower Bound S-5: Area-wide Removal (Lower Bound Step Down)